BUILDING MATH SELF-EFFICACY: A COMPARISON OF INTERVENTIONS DESIGNED TO INCREASE MATH/STATISTICS CONFIDENCE IN UNDERGRADUATE STUDENTS

BY

KAREN JOAN FORBES

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1988

ACKNOWLEDGEMENTS

I have been very fortunate to have a committee composed of dedicated, caring, and gifted teachers and scholars each of whom has made a unique contribution to both my professional and personal development. Dr. Greg Neimeyer has given me support and guidance from the moment I began my graduate program. His patience and consistently positive reinforcement as I struggled to define myself as researcher, teacher, and therapist were always greatly appreciated.

I would also like to thank Dr. Larry Severy who first urged me to take on this project and who has been a friend and supporter throughout my graduate program, Dr. Helen Mamarchev who has been a wonderful role model for my professional and personal life, and Dr. Paul Schauble, who has helped me to set high goals for myself as a professional psychologist and as a person. Very special thanks go to Dr. Barbara Probert for her wonderful friendship and her mentoring. Because she always believed in me, it has been easier for me to believe in myself.

This project would not have been possible without the generous financial support of the College of Liberal Arts and Sciences, the Department of

Psychology, and the alumni fellowship committee of Oberlin College. I also appreciate the efforts of the Department of Statistics to support and to understand the purposes of my research. Most importantly, many thanks go to my committed, caring counselors and tutors who gave their time and professional expertise so that this project would be successful.

I would like to acknowledge all of the students who participated in this project. I hope that this experience helped them to feel more confident about their mathematical ability. They were all intelligent, thoughtful people, and I wish them much success in all their endeavors.

Finally, there are several people who have given me endless support and love throughout this process. Dr. Kathleen O'Connor and Bill O'Connor have been extraordinary friends and employers without whom I literally could not have completed my dissertation. My parents, Donald and Carole Forbes, my brother, Doug, and my husband, Larry Gage, have never failed to let me know how proud they are of my goals and my achievements. Their love and constant support have helped me to weather the bad times and to take joy in the good times. I share all of my accomplishments with them.

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By

Karen Joan Forbes

August 1987

Chairperson: Greg J. Neimeyer
Major Department: Psychology

Because many students lack confidence in their ability to succeed in mathematics courses and careers, the United States faces a serious shortage of people with the skills necessary to sustain and to develop the advanced technology on which our society depends. This study was carried out to determine the comparative effectiveness of two intervention strategies for increasing mathematics self-efficacy in undergraduate students and to assess the feasibility of implementing a math/statistics confidence program within an academic department at a major university.

Undergraduate students at a large southern university were informed that the department of psychology was implementing a pilot program to help students deal with apprehension about required statistics courses. One hundred and sixty-nine students

completed a variety of pretest measures and 96 indicated an interest in being involved in such a program. Students were randomly assigned either to one of four counseling-based statistics confidence groups, to one of three statistics tutoring groups, or to a no-treatment control group. The experimental design was a repeated measures paradigm where students were given pre- and posttreatment assessments of math self-efficacy, math anxiety, self-reported math ability, and math self-concept.

Results showed that at posttest, math confidence groups rated themselves as having significantly higher math/statistics ability than either the tutoring or control groups. Both experimental groups significantly lowered their levels of math anxiety relative to the control group. The differences between the two experimental groups in the number of implications that mathematical ability had on students' self-concepts approached significance, with the math confidence groups having fewer implications. There were no signficant differences among the three groups regarding math self-efficacy or final statistics grade. Correlational analyses performed on the experimental data and the pretest data from the original sample of

169 students lend some support to earlier findings regarding the relationships among math self-efficacy, math anxiety, sex-role orientation, and academic performance.

INTRODUCTION
CHAPTER ONE

Probably at no other time in our nation's history is a knowledge of mathematics so essential. The American people and their government representatives are repeatedly being called upon to make decisions on issues such as the Strategic Defense Initiative, the federal deficit, the new tax laws, and the Space Shuttle program. Although it is not necessary to be intimately familiar with all of the details of these programs, complete ignorance and the need for the American people to rely on a few "experts" does not bode well for the democratic decision-making process.

Diminishing Numbers of Qualified Mathematicians

Although a lack of understanding of scientific and mathematical issues is a serious problem, an equally serious threat is a dearth of trained mathematicians and scientists. The 1986-87 Occupational Outlook Handbook (Bureau of Labor Statistics, 1986) reports that there is currently a shortage of Ph.D. mathematicians which is expected to continue throughout the decade. Individuals holding master's and bachelor's degrees in mathematics will benefit from this shortage. Many job opportunities in computer science and data

processing will become available, and by meeting state certification requirements, many will find openings in secondary education.

Mathematical work can be categorized as either theoretical (pure) or applied. Although theoretical mathematicians seek to develop new principles and relationships without necessarily seeking practical applications of their work, their findings are often the basis of important applied technologies, as in the case of Rieman's non-Euclidean geometry and the creation of atomic power (Bureau of Labor Statistics, 1986). Applied mathematicians find employment in business, government, engineering, natural and social sciences; however, as the Bureau of Labor Statistics points out, "the number of workers using mathematical techniques is many times greater than the number actually designated as mathematicians" (Bureau of Labor Statistics, 1986, p.76).

Although an abundance of job vacancies is welcome news for those with degrees in mathematically related fields, it is troubling to think of shortages in areas so vital to our nation's economy. These labor statistics also raise questions about why so few of our vocationally oriented college students are pursuing

math and science majors that would almost guarantee them employment.

The United States Department of Education monitors the number of degrees conferred by institutions of higher education. In 1982-83, there was a 50% decline in Bachelor's degrees granted in the discipline of mathematics, 12,543 down from 24,801 in 1970-71. Of the 30 disciplines listed in the Digest of Education Statistics (Grant & Snyder, 1986) only library science, foreign languages, and letters had a similar or greater decline (Grant & Snyder, 1986, p. 129). The number of master's degrees in mathematics declined by 45% from 1970-71 to 1982-83, and 42% fewer Ph.D.'s were granted in 1982-83 than in the decade before. Again, only the disciplines of library science, foreign languages, and letters suffered a greater reduction in master's degrees over the previous decade, but mathematics emerged with the greatest losses in the numbers of Ph.D.s granted (Grant & Snyder, 1986, p. 129).

Education has been especially affected by the diminishing numbers of math graduates because employers in private industry and government offer much higher salaries to people trained in mathematics, science, and

computer programming (Bureau of Labor Statistics, 1986, p.129). During the 1981-82 academic year, 1,897 students received degrees in art education, 4,915 in music education, and 17,391 in physical education. Only 529 degrees were granted in mathematics education and 558 in science education. In 1982, although 17,000, or 9% of the nations's math and science teachers left their jobs, only 700 recently graduated math and science education majors began teaching.

In the case of elementary education, many teachers do not enjoy mathematics, nor do they feel it is important. Bulmahn and Young (1982) found that many of the elementary educators they interviewed considered math to be their worst subject, and as a result, felt their career options had been limited. What was most disturbing to the investigators was the feeling expressed by many beginning education students that "elementary teachers do not really have to be very good at mathematics beyond the basic computations" (Bulmahn & Young, 1982, p. 56). Furthermore, Kelly and Tomhave (1985) found elementary education majors to be highly anxious about performing mathematical tasks, a result supported by Probert (1979).

Although it is debatable whether or not increasing teacher salaries will entice students trained in math and science to become elementary or secondary school teachers, it would seem possible that the current situation is forcing us into a vicious cycle. Because our country is producing fewer qualified mathematicians, there will be that many fewer in classrooms motivating children to take advanced coursework and to pursue careers in mathematics and related fields.

Factors Affecting Mathematics Achievement

Along with the decline in the numbers of mathematicians has come a corresponding decline in standardized test scores. From 1961 to 1981, average SAT scores fell from a total of 969 to 890, after which a small increase occurred bringing the current average to 906 (Bremelaw, 1986, p. 86). The *Digest of Education Statistics* (Grant & Snyder, 1986) records the average quantitative SAT score for females as 467 in 1967 and 449 in 1984. For males, the average quantitative score declined to 495 in 1984 from 514 in 1967. What is especially significant about these data is that Americans are currently spending over $80 million and

countless hours on SAT preparation courses (McCabe, 1986).

The Digest of Education Statistics (Grant & Snyder, 1986) lists the results of two international studies of mathematics achievement which included students from Belgium, Canada, England, Finland, Hong Kong, Hungary, Israel, Japan, the Netherlands, New Zealand, Nigeria, and Scotland. As compared to students in Japan, our foremost technological rival, American students performed quite poorly on mathematics tests. On the average, Japanese students answered correctly 76% of algebra items, 69% of the calculus items, 76% of the geometry items, and 72% of the probability and statistics items. By comparison, American students responded correctly to 43% of the algebra items, 29% of the calculus items, 31% of the geometry items, and 40% of the probability and statistics items. The median percent correct for all 14 countries was 57% for algebra, 44% for calculus, 42% for geometry, and 50% for probability and statistics.

Mathematics Requirements in Secondary Education

Perhaps this wide gap in mathematical proficiency can be attributed to the differential amount of time spent on mathematics in American schools. Of the 14

countries in the above-mentioned international study, three countries had a lower proportion of students of appropriate age taking advanced mathematics classes than students in the United States, five countries had about the same proportion, and six had a higher proportion.

In 1984, although only 10 states allowed fewer than four years of high school English for graduation, 41 states did _not_ require any more than two years of mathematics (Grant & Snyder, 1986, p. 44). The average number of Carnegie units in mathematics earned by high school graduates in 1982 was 2.5, demonstrating that students did not feel motivated to pursue mathematics after they had completed their requirements. Students in public schools took the fewest number of math courses, an average of 2.5, while Catholic school graduates earned an average of 3.3 Carnegie units in math, and non-parochial private school students averaged 3 math courses. It is interesting to note that students of Asian descent took the greatest number of math courses, an average of 3.1, while students of Native American heritage had the lowest average number of mathematics courses, 2.0. Likewise, 70% of Asian-American students took the SAT or ACT as compared

to 30% of white students and 28% of all students (Jacobson, 1986, p. 108).

Students' Perceptions of the Usefulness of Mathematics

There appears to be a direct relationship between career aspirations of students and the number of mathematics courses they complete in high school. In the "High School and Beyond" survey done in 1982 by the United States Department of Education, (cited in Grant & Snyder, 1986) students were questioned about their post-secondary plans. Those who had planned no further education had taken an average of 1.9 math courses, whereas those who planned to obtain a four year degree had taken an average of 3.1 years of mathematics.

During the same year that the "High School and Beyond" survey was conducted, Armstrong and Price (1982) queried 1,788 high school seniors about the factors that were most influential in their decision to enroll in mathematics courses. The most significant motivator was their perception of mathematics' "usefulness" in their future lives. Evidently, the average non-Asian American student does not perceive mathematics to be important for his or her post-high school life.

Students may not realize just how many college majors and careers require extensive mathematics preparation. In one of the first studies addressing the problem of math avoidance, Lucy Sells (1973) dubbed mathematics the "critical filter," because over 75% of the college majors at the University of California at Berkeley required advanced mathematics. Sells (1973) was also one of the first investigators to point out the differential enrollment of young men and women in high school and college math courses. Since then a great deal has been written about the reasons why men are more likely to enroll in mathematics and science courses and to pursue math-related careers. This is an issue of considerable importance because "scientists and engineers exert considerable influence on United States society, any group that contributes few scientists and engineeers is at least partly disenfranchised" (Goldman & Hewitt, 1976, p.50). Results have been equivocal concerning the existence of reliable differences in mathematical aptitude between men and women, however a sex-role socialization hypothesis has become one of the most popular explanations given for math avoidance.

Confidence and Enrollment in Math Courses

The second most important variable that Armstrong and Price (1982) found determined mathematics enrollment was students' confidence in their ability to do well in math courses. The "High School and Beyond" study uncovered a supporting relationship between actual test performance and enrollment in math courses. Those who performed most poorly on an academic test battery averaged the lowest number of math courses, 1.9, while those who scored highest took the greatest number of mathematics courses, 3.3. This is in contrast to enrollment in English courses where low scoring students still took an average of 3.4 courses, as compared to 3.8 courses taken by the highest scoring students, and to social science where the difference between low and high scoring students was 2.5 and 2.7, respectively. In the case of English and social science (usually History), students have little choice about how many courses they take, regardless of how poorly they perform in these classes. With mathematics, students who are not successful may opt to deal with their deficiencies by avoiding the subject altogether.

Strategies for Teaching Mathematics

The quality and type of math instruction have been offered as a reason for students' poor performance and subsequent avoidance of non-required mathematics courses. Jay Greenwood, a mathematics educator in Portland, Oregon, believes that students would be more adept at and more interested in the subject if teachers would abandon the "explain-practice-memorize" approach to mathematics (Greenwood, 1984). Greenwood feels that this teaching strategy "promotes and perpetuates that all too common perception of mathematics as a subject that appears easy and logical to a few 'brains' and incomprehensible to most common folk" (Greenwood, 1984, p.663).

There is little question that the data reported above point to a current and increasing deficit of Americans trained in mathematics and related fields. What is not as clear are the factors responsible for this trend. It is difficult to untangle the lines of causality; should poor mathematics performance be attributed to inadequate academic preparation or rather are students choosing not to pursue additional math courses because they have not performed well? Either scenario produces even more questions. If the former is

true, why have educators decided that mathematics is not important enough to require three to four years of coursework; is this attitude promoting a feeling among students that mathematics is not "useful?" If the latter is the case, what is it about our educational system that is not producing successful learners of mathematics?

Mathematics Anxiety

Since the early 1970s the construct of "math anxiety" has become a popular explanation for the diminishing numbers of American students pursuing advanced mathematics coursework and math-related careers. Upon offering a behavioral therapy program through the Colorado State University Counseling Center, Frank Richardson and Richard Suinn found that a third of the students responding indicated that their problem related to anxiety about mathematics courses (Richardson & Suinn, 1972). These two researchers and therapists described mathematics anxiety as "involving feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (Richardson & Suinn, 1972).

In 1976, Sheila Tobias stated that math anxiety was a promising construct for understanding avoidance behavior in mathematics. Byrd (1982, cited in Reyes, 1984) found that students claimed math anxiety to be the cause of avoiding not only math courses, but certain jobs, science courses, some careers, tests, balancing the checkbook, and colleges with heavy math requirements. As early as 1954, Gough defined number anxiety as "the presence of a syndrome of emotional reactions to arithmetic and mathematics" (p. 344). Fennema and Sherman's (1976) Math Anxiety Scale was designed to "assess feelings of anxiety, dread, nervousness, and associated bodily symptoms related to doing mathematics" (p. 4).

Researchers such as Nancy Betz (1978) and Darwin Hendel have produced data that suggest that large numbers of college-aged students are experiencing math anxiety (Hendel & Davis, 1978), while more recent studies have failed to confirm these findings (Resnick, Viehe, & Segal, 1982). However, each of these studies reported that math anxiety was greater in the cases of students with weak mathematical backgrounds. Hendel and Davis (1978) believe that "one symptom of mathematics anxiety is avoidance of mathematics" (p. 430).

Mathematics Anxiety as a Unique Construct

Reyes (1984) believes that even though there has been a "flurry of activity" around math anxiety since 1977, much of the discussion has not been grounded in research knowledge (p. 563). Many investigators do not accept that 1) math anxiety is a separate construct from test anxiety or that 2) anxiety, with all of its attendant physical symptoms is an appropriate term.

Byrd (1982, cited in Reyes, 1984) defines test anxiety aroused by evaluative situations. Wine (1971) has divided test anxiety into two parts, worry, which is the cognitive concern about one's performance, and emotionality, the arousal of the autonomic nervous system in evaluative situations. Dendato and Diener (1986) describe Wine's (1971) Cognitive Attentional Model as proposing that students suffering from test anxiety are impaired by "worry, negative self-evaluative statements, and task irrelevant ruminations that compete for attentional capacity with task relevant activity and interfere with the recall of pertinent information" (p. 131).

Dew, Galassi, and Galassi (1984) investigated both the uniqueness of the math anxiety construct and the physiological correlates in their study entitled, "Math

Anxiety: Relation with Situational Test Anxiety, Performance, Physiological Arousal, and Math Avoidance Behavior." The heart rate, skin conductance, and skin fluctuations of undergraduates were measured when they were given math problems to solve under test equivalent conditions. The students were also asked to complete a variety of other assessments measuring test anxiety, math anxiety, and math aptitude. Dew et al. (1984) found that the measures of math anxiety were generally correlated with test anxiety. Math anxiety was inversely correlated with performance on math problems, however it was not significantly related to any of the physiological measures.

Proponents of the math anxiety construct believe that individuals only experience the cognitive attentional deficits described by Wine (1971) when the situation involves mathematics. Rounds and Hendel (1980) have suggested that "mathematics anxiety is less a response to mathematics than a response to evaluation of mathematics skills" (p. 146). Rounds and Hendel were led to such a conclusion based on their analysis of the Richardson and Suinn (1972) MARS. They concluded that the MARS is not measuring a homogeneous factor called "math anxiety," but rather two distinct factors which

they described as follows:1) Mathematics Test Anxiety--apprehension about taking and receiving the results of math tests, and 2) Numerical Anxiety--everyday concrete situations requiring number manipulation. (Rounds & Hendel, 1980).

Rounds and Hendel (1980) are concerned that the Richardson and Suinn (1972) definition of math anxiety is not broad enough to encompass the diversity of the field of mathematics.

> If the "solving of mathematical problems" is considered within the context of mathematics tests, the two MARS factors identified are a good fit to that definition. However, the fact that mathematics is a very broad field makes this and other definitions of the mathematics anxiety domian problematic. (Rounds & Hendel, 1980, p. 145)

Self-Efficacy Theory and the Problem of Math Avoidance

Although the MARS describes an individual's reactions to certain mathematically related situations, it provides little or no explanatory value as to why mathematics produces such anxiety. In order to alleviate the distress that individuals are reporting, counselors and educators need a theoretical framework within which they can develop effective treatments. Rounds and Hendel (1980) warn that the label, "math anxious" is both limited and "linguistically ambiguous,

suggesting a pathological response to mathematics per se" (p. 146).

Ultimately, math anxiety is only an important construct insofar as it explains either poor performance or avoidance of mathematics when to do so is harmful to an individual. There are those who may never experience nervousness because they can successfully avoid all contact with the subject. Avoidance is, in effect, a "cure" for math anxiety. However, the true problem is that thousands of students are avoiding the math courses that will prepare them for a myriad of careers, that will allow them to be knowledgeable about technological issues that face the country, and at the very least, will enable them to perform functions such as managing their personal finances. Anxiety and avoidance are part of a cycle whose origin is very difficult to pinpoint.

Recently, Nancy Betz and her colleagues have begun to advance Bandura's Self-Efficacy Theory as a context within which to explain individual's avoidance behavior towards mathematics courses and careers. Bandura has posited that a person's beliefs in regard to his or her ability to perform a certain task are the major agents of behavior and behavior change (Bandura, 1977). These

beliefs about one's abilities, or self-efficacy expectations, are learned and modified by four sources of information: 1) performance accomplishments, 2) vicarious learning or modeling, 3) verbal persuasion, and 4) emotional arousal. Betz and Hackett (1983) explain that Bandura believes anxiety to be a co-effect of self-efficacy expectations; as self-efficacy diminishes, anxiety increases. Therefore, anxiety is not viewed as the cause of avoidance behavior but as a byproduct of low self-efficacy. And unlike Hendel and Davis (1978) who see avoidance as a symptom of math anxiety, self-efficacy theory would explain both anxiety and avoidance as by-products of low self-efficacy expectations.

Self-efficacy theory can offer a theoretical framework for the results produced by studies proposing teaching styles, sex-role stereotyping, and even physiological deficits as underlying causes of math avoidance behavior, since all of these factors can affect one's self-statements and beliefs about one's ability to perform. It also allows for people who may have experienced similar mathematical instruction or who have been exposed to similar sex-role stereotyping

to behave differently in situations calling for contact with mathematics since their perceptions of the situation and their abilities may lead to different expectations.

Building Math Self-efficacy Expectations

Unlike explanations of math avoidance that rely on nearly immutable factors such as gender role and physiology, self-efficacy theory provides the mechanism whereby a person's belief system can be modified, leading to increased confidence and in many cases, reduced anxiety. "Interventions focused on increasing self-efficacy expectations via attention to the sources of efficacy information should increase approach versus avoidant behavior and concurrently, decrease anxiety in relationship to the behavior" (Betz & Hackett, 1983, p. 331). As Bandura (1986) has recently noted, however, no consistent relationships have been found between changes in fear arousal and phobic behavior, so merely modifying anxious responding will not guarantee an increase in confidence about performing a certain task.

The following study attempts to show the superiority of a multimodal intervention in increasing self-efficacy expectations of undergraduate students enrolled in an introductory statistics course as

compared to a traditional tutoring approach and a control group. Unlike interventions that have focused on reducing anxiety, the groups were based on Bandura's notion that it is not fear or anxiety that produces avoidant behavior, but expectations that one will fail at a task (Bandura, 1986). Thus, the students were involved in math confidence groups, rather than in groups that focused exclusively on reducing math anxiety.

In the subsequent chapter, a more detailed history of the theorizing and research performed in the area of math anxiety and avoidance will be discussed, including the role of mathematics instruction, sex-role socialization, and physiology. Bandura's theory of self-efficacy and the studies which have attempted to use this framework as an explanation for math avoidance behavior will be explicated. Finally, a review of previous counseling interventions used to alleviate "math anxiety" will be discussed and contrasted with the approach used in this study. Chapters Three, Four, and Five will describe the measures and procedures under which the study was executed, the results of the various group by group comparisons and post-test measures, and the conclusions suggested by the data.

CHAPTER TWO
REVIEW OF THE LITERATURE

On January 26, 1987, the Public Broadcasting System premiered a children's show entitled, "Square One" whose intention it is to teach mathematics in a way that is lively and entertaining. The following remarks were culled from a review of the program by <u>Washington Post</u> staff writer, Megan Rosenfeld.

> As a certified math idiot, I approached the new children's TV series on the subject, "Square One Television" with particular interest. . . .It is geared to children 8 to 12 years old–about the age my math education ceased...Frankly, I don't think there is much you can do to make math interesting, and frankly, this program doesn't do much to disprove that idea. . .I am, alas, not the only person suffering the heartbreak of math illiteracy. In fact, I was able to find someone worse at it than I am and marry him. (1987, p. B8)

There are not many subjects in which adults will publicly declare there inadequacies let alone state that they are "idiots." However, mathematics seems to be an area about which it is all too acceptable to be ignorant. Ms. Rosenfeld continues by describing a segment of the show in which she encountered particular difficulty, a lesson about prime numbers, in which the

number fourteen was declared "not a prime number." "Now admittedly, I had to take college remedial math twice and never had 'new math,' but what the heck is a 'prime number'--and why should we care?" (Rosenfeld, 1987, p. B8). Imagine someone writing about something so fundamental to our language as a verb and asking why should we care what it is?

There are many tragedies embodied in this light-hearted, sarcastic review. First is the idea that mathematics is useless and that one can be a perfectly successful adult without having further than a sixth grade-level understanding of basic arithmetic principles. Secondly, the author dismisses the possibility that mathematics can be interesting, leading the reader to infer that anyone who disagrees is somewhat odd. Finally, Ms. Rosenfeld alludes to having a child in the age group to which the show is geared. One can expect that with two parents who proudly announce themselves to be mathematical illiterates, this child is not likely to grow up eager to learn this subject.

There has been a great deal of research documenting Americans' negative attitudes towards mathematics. A somewhat smaller number of studies have

proposed either causes or solutions to this problem. Many of these investigations have included, the term, "math anxiety" in their titles. In 1978, Patricia Casserly of the Educational Testing Service told the National Council of Teachers of Mathematics that mathematics anxiety was "often used to conveniently lump together all sorts of phenomena associated with learning mathematics" (p. 7, cited in Rounds & Hendel, 1980). It is as if when we can determine the "causes" of math anxiety we could increase the academic performance of students, raise the numbers of women and minorities in mathematical professions, and produce a more technologically sophisticated populace. In 1980, Rounds and Hendel had already accumulated enough evidence to dispute these claims, leading them to suggest that both the construct of math anxiety and the tests which purported to measure it were in need of serious revision if they were to be useful in the understanding of mathematics learning and performance.

The following review will examine the many studies which have claimed to study "math anxiety," including descriptions of negative attitudes toward mathematics, the relationships between personality and demographic characteristics and math attitudes and aptitude, and

the effects of teaching strategies on math anxiety and performance. But even more importantly, an attempt will be made to determine whether or not the whole concept of math anxiety is useful in contributing to our understanding of how a person is unsuccessful in his or her efforts to become proficient in mathematics.

Images of Mathematicians

Try the following exercise. In your mind, picture a mathematician. Attempt to visualize how the person is dressed. Imagine yourself meeting this person for the first time; how do you feel? Now create a mental picture of yourself in a room filled with mathematicians. Where do you sit in the room? Are you comfortable in this environment. ("Picture A Mathematician," Probert, 1983).

I have posed these questions on many occasions to people of both sexes, of varying ethnic backgrounds, age groups, and educational backgrounds. With few exceptions, the images revealed a stereotype of a mathematician as a white, male, with eyeglasses who is uncomfortable socially and who dresses in a somewhat outdated fashion.

Even more important than the rather negative characterizations of mathematicians are the feelings of intellectual inferiority reported by subjects. Many

persons have described the mathematician as being gigantic in height while they shrink to tiny proportions. One young woman even saw herself as a dot rather than a human being. Needless to say, being in a room filled with mathematicians was not a comforting experience for these people!

Almost every stereotype has at its core a grain of truth, but ironically, many of the students reported knowing mathematicians who had very few, if any, of these characterisitics. Kogelman and Warren (1978), in their book, Mind Over Math, relate an anecdote about a party they attended. Even though they were both young, attractive, casually dressed, and outgoing, when people to whom they were introduced discovered that they were mathematicians, the conversations ended abruptly.

Kogelman and Warren (1978) have developed a list of "math myths," commonly held yet false beliefs about mathematics and mathematicians. Many of these myths fall broadly into two categories. Some of the myths are authoritarian, that is they proclaim that mathematics must be performed in a certain way, and that way only. The second category is composed of myths having to do with the types of people who can do mathematics; the "math people" are male, smarter, more logical, have

better memories, and less creative than "language people" (Kogelman & Warren, 1978).

A number of studies have tested empirically these stereotypes about persons who are successful in mathematics and related fields. McNarry and O'Farrell (1971) found that students viewed scientists as "helpful, wise, and important, but hard, old, frightening, and colorless" (p. 1060). Lorelei Brush (1980) expected that mathematicians would be viewed in a similar way. She asked high school and college students of both sexes to contrast their idea of a "typical" mathematician with their idea of a "typical" writer using a semantic differential. Finally, the students' self-images were compared to each of the above professions.

The semantic differential items were grouped into factors which resulted from the prinicipal components factor analysis. Writers were described as creative, individualistic, independent, and sensitive. Mathematicians, however, were viewed as being rational, wise, responsible, and cautious. There was almost complete unanimity between high school and college samples. Both sexes felt their own image of themselves was more compatible with their stereotypes of a writer

than with a mathematician, even though the traits assigned to mathematicians are considered exclusively masculine (Bem, 1974).

A similar study was conducted by Naomi Rotter (1982) in which she sampled students at engineering and liberal arts colleges in New Jersey. Students were asked to rate their peers who were engineering majors, math/science majors, or liberal arts majors such as sociology and psychology using 30 bipolar trait items (i.e. ambitious-lazy, friendly-unfriendly, attractive-unattractive, etc.). As compared to female liberal arts majors, women majoring in engineering were perceived as less friendly, less attractive, less flexible, and as having a poorer sense of humor. However they fared better in comparison to their male engineering-major counterparts who were believed to possess these traits to an even lesser degree.

These studies support the notion that in general, students do not think of themselves as "mathematicians." To call oneself a mathematician, is to declare that one is purely rational, lacking in creativity, and unattractive socially. It would appear that the social stigma of being interested in and adept

at mathematics far outweighs the benefits of learning the subject.

Brush (1980) proposes a number of explanations for why young people view mathematics so negatively. She feels that students are probably quite ignorant of the daily lives of both mathematicians and writers. Students ignore the tedious background research and methodical plotting of storylines that writers must perform and, furthermore, have a narrow conception of the myriad careers writers pursue other than writing novels. Likewise, mathematicians use many of the skills the students' in Brush's and Rotter's studies attributed only to liberal arts types of professions. Brush (1980) writes:

> A mathematician in her or his research must be flexible in the ideas she or he is juggling, prepared to reject others' frames of reference and create a new image of a problem. This flexibility and creativity --this independence from givens--seems antithetical to the common notion of rational thought as a linear, clearly defined process of arriving at a conclusion. (p. 234)

Mathematicians, themselves, may even foster these stereotypes. Some have admitted that they did not want those outside of the field to learn about what they were doing. It was a tradition to share discoveries

only with those who intimately understood their work, but unfortunately, this attitude prevented persons in a position to support funding for mathematical research from having the necessary information (McDonald, 1986).

An article in the Chronicle of Higher Education points out that unlike other scientists who work with concrete objects or substances, the realm of the mathematician is largely abstract or imaginary. Often, his or her work is solitary, done without the help of technical staff or graduate and undergraduatee assistants. Irving Kaplansky, director of the Mathematical Sciences Research Institute in Berkeley has said, "It's the only profession I know of where you can lie at home with your feet on the couch and tell your wife that you're working" (McDonald, 1986, p. 5).

However, even mathematicians who thought their work too abstract to ever be used for practical purposes have been proved wrong. Increasingly, scientists have found solutions to complex problems in mathematical theories developed decades earlier. The Chronicle reports that mathematicians often have difficulty distinguishing their work from that done by physicists, astronomers, and economists (McDonald, 1986, p. 5).

Ralph Slaught, chairperson of the Department of Philosophy at Lafayette College, theorizes that most colleges and universities hold the belief that "aristocrats do not get their hands dirty" and thus separate the "thinkers" from the "doers" (1987, p. 38). He quotes from both James Adams, a Stanford engineer who recalled how the Greeks provided formal education only to the elite with foreigners, slaves, and businessmen doing "work" and from John Dewey, who proposed that "our distaste for work itself extends to those who must do it" (Slaught, 1987, p. 38). Slaught warns that we cannot merely take courses "about" technology, but must be conversant with the methods of science. "We cannot make intelligent decisions about how to deal with technology without an adequate understanding of the processes involved. Without that we are forced to defer to the expert or pseudo-expert and in doing so we surrender some of our freedom" (Slaught, 1987, p. 39).

Somehow, we must impress upon our young people the gravity of the consequences about being ignorant about the principles underlying advanced technology. The image of socially inadequate, isolated mathematicians and scientists must be replaced by that of vital,

creative, and powerful contributors to society. The classroom is the most obvious place to look for both the birth of negative stereotypes of mathematicians and the means to change these images.

The Effect of Teaching Strategies on Mathematics Attitudes and Achievements

The preceding section focused on the effects of myths about the personality characteristics of people who are successful in math. Kogelman and Warren (1978) have also uncovered myths about the field of mathematics itself. Many believe that there is only one right way to arrive at a correct answer and that mathematicians divine these answers by having superior powers of memory and logic and by knowing the "tricks" inherent in mathematics.

Many educators and mathematicians have laid the blame for these false beliefs at the feet of the schools. Whereas teachers cannot be held responsible for all of our nation's problems with mathematics, they are often the first people to introduce mathematical concepts to children and thus have great influence in the development of attitudes toward the subject.

Greenwood (1984) describes the typical approach to teaching mathematics as the "explain-practice-memorize"

teaching paradigm, of which he has numerous criticisms. This method gives little or no attention to developing children's logical thought processes or reasoning abilities that are the basis for mathematical principles (Greenwood, 1984). Rather it focuses on computing "right" answers and instills in children the feeling that there is a "trick" or magic solution to math to which they do not have access but must accept on faith. As Greenwood (1984) says, this memorization-based approach perpetuates the notion that mathmematics is a subject that "appears easy and logical to a few 'brains' and incomprehensible to most common folk" (p. 663).

Another commonly voiced criticism is that basic math skills are taught as distinct from higher order problem solving. James Sandefur, a mathematics professor at Georgetown University, asks us to imagine that students took two years of grammar, one year of spelling, and then spent two years studying authors' use of symbolism before they finally read a novel (Sandefur, 1987). Although this method of teaching English seems ridiculous, Sandefur sees mathematics as being taught in an equally absurd fashion.

Rarely do teachers of algebra teach formulas within the context of solving a particular problem, and because so few students perservere in math to take applied courses, many never realize the importance of math (Sandefur, 1987). Sandefur agrees with Slaught (2/18/87) when he proposes that mathematicians enjoy the "mystique" of their science and "don't want to defile...[their] art by teaching applications" (1987, p. 38). He criticizes his colleagues for failing to develop new courses, as do professors in other disciplines. Because non-mathematicians know so little about the subject and are so easily intimidated by those who do, it is the responsibility of the mathematicians to develop new educational frontiers in thier field (Sandefur, 1/21/87).

The International Association for the Evaluation of Educational Achievement (1985) recently published its Second Study of Mathematics Summary Report in which it related the poor math performance of American students to the manner in which the subject is taught. In eighth grade, American students scored only slightly above the international average in computational arithmetic, whereas they were already significantly below the average of other countries in problem solving

capabilities. However, by the twelfth grade, calculus students in the United States ranked as low as the bottom quartile among international students.

The study concludes by describing the American eighth grade curriculum as "low intensity," dealing only superficially with topics in the space of one or two class periods. The authors of the study propose that this approach prevents students from developing a firm conceptual foundation on which to learn other forms of mathematics. This method was most notably in contrast with the more "intense" approach favored by the Japanese. Furthermore, the study states that the United States high school curriculum is highly compartmentalized, teaching algebra I, geometry, algebra II, and then trigonometry, analytic geometry, or calculus in the fourth year. In other countries mathematics is taught in a more integrated manner so that students may see the relationship between different areas of math. The authors of the study recommend that the fragmented, low-intensity approach to teaching mathematics in the United States be forsaken in favor of a more integrated curriculum.

After graduating from high school in the United States, students may perceive mathematics to be a

rather abstract discipline with few applications outside of the classroom. If they pass their courses using the "memorization" approach, they may graduate from high school with little recall for the material taught by their math teachers. These students may feel they have missed the "trick" of doing math; they may conclude that they do not have a "mathematical mind" (Kogelman & Warren, 1978).

It is not difficult to see how these mathematical myths about the proper way to do math and the proper personality or temperament for mathematics came about. In our system of math education, those students who have a preference for logic, rote memorization, and non-verbal approaches are more likely to succeed in a classroom that emphasizes such a learning style. But that is not to say that persons with alternative learning preferences cannot enjoy or achieve in math. A recent attempt at updating the strategies for teaching math in California met with limited success. Textbook manufacturers spent millions of dollars on revisions designed to overcome negative attitudes and outdated instruction methods only to be met with resistance from teachers. Teachers continued to choose

traditional books because they looked and felt familiar (All Things Considered, 1987).

Research on learning styles has already shown that children learn more quickly and are able to master subjects which they previously found impossible when they are taught through their indiviudal learning styles (Hodges, 1983). Unfortunately, those who become teachers often learn only one method of teaching math and they lack the knowledge to use alternative approaches.

Teacher Attitudes Toward Mathematics

The problems with mathematics education are not confined to the manner in which the concepts are taught. Of equal concern are the attitudes about the importance of mathematics that may be transmitted by instructors. Bulmahn and Young (1982), a mathematician and a psychologist, conducted a descriptive study to investigate the mathematical experiences and attitudes of elementary education majors in contrast to other students.

Bulmahn and Young (1982) asked students to complete a questionnaire which included questions regrading demographic data, perceived difficulty of academic disciplines, math courses taken, level of

anxiety about doing math, and its implication for career choice. Not surprisingly, students favored subjects in which they did well. There was a consistent relationship between preferences for mathematics and science and language and social studies, however correlations between the two discipline dyads were insignificant or negative.

In the second part of the study, students were asked to compose essays on their mathematical background. The investigators reported a large number of students who revealed that math had been their worst subject and who felt that their dislike for the subject had limited their career opportunities. What was most disturbing to Bulmahn and Young (1982) was the belief held by many of these students that it was not really necessary for them to know mathematics beyond the basic computations. They concluded that for many elementary education teachers, "mathematics is at best a necessary evil" (Bulmahn & Young, 1982, p.55).

> In general, the kind of person who is drawn to elementary school teaching is not necessarily the kind of person who enjoys mathematics in the broad sense--from its logical beauty to its real world applications. As a matter of fact, these two areas of preference, elementary school teaching and mathematics, may have some

> inconsistencies between them. (Bulmahn & Young, 1982, p.55)

Bulmahn and Young (1982) express alarm at these attitudes, yet their suggestions and conclusions perpetuate some of the worst stereotypes about select groups of people who can "do math." They suggest that further research be done on whether being good at math is incompatible with being a good elementary teacher and whether people who are interested in math are likely to be interested in teaching. They even suggest that math specialists be placed in schools to compensate for lack of teacher knowledge and expertise. Although this is a possible short-term solution and one the teachers might even welcome, it would seem more important to change the negative attitudes of those planning a career in elementary education, especially when school systems are having difficulty paying teachers' salaries, let alone the salaries of special math experts.

To say that only certain female, verbal, humanistic personality types can be teachers is equally as bad as saying that only white, male, logical, uncreative people can be mathematicians. Rather than devising schemes to match personality types with our

stereotypes of what qualities certain professions demand, educators should consider putting their energies into disputing preconceived notions that so many students have about careers.

Recently, there have been some attempts to help teachers become aware of the way students can best learn mathematics. One of the most inventive and successful programs is at Indiana University, where non-math/science professors are reliving their college days by attending undergraduate physics classes. The aim of the project is to have skilled, motivated learners help physics professors devise better ways to communicate their subject matter. Sheila Tobias, who directs the project, explains:

> Students who could critique the class-those for whom the material doesn't make sense-either fail or simply drop from the rolls. Often the instructor never finds out what is wrong. Faculty members have the confidence, self-awareness, and ability to analyze why they find something difficult (McMillen, 1986, p. 18).

The professors take an introductory course required for non-majors who plan to take science or math courses. Over a quarter of the students withdraw before the end of the semester, thus disqualifying themselves from many majors. Many of these drop-outs

are women and minorities, according to the professor who teaches the course.

The Department of Physics at Indiana University has already made significant changes in the laboratory sections of the class, emphasizing discussion and writing, rather than a purely quantitative analysis of the class material. The discussion leader employs the Socratic Method, and the lab is called, ironically, S.D.I., for Socratic Dialogue Inducing.

But even with these changes, the professors, those proven-successful learners, become anxious. A psychology professor found his "whole life flashing before. . .[him]. . .it was the math that stumped me", he said (McMillen, 1986, p. 18). A professor of English said that he felt rushed and would think, "I don't understand this. . .I have never understood this. The problem starts when math is introduced to the course" (p. 19). It is not difficult to imagine what undergraduates feel when even experienced academicians lose confidence in their ability to grasp scientific and mathematical concepts.

It is somewhat understandable that non-math and science professors feel anxious about material that they have not studied for years, if ever. However when

people who are teaching math are anxious the consequences are much more serious. Kelly and Tomhave (1985) compared several different age groups who had little or no math preparation, a group of students participating in a workshop for math anxiety, and a group of elementary education majors on their levels of anxiety about mathematics. The elementary education majors were the most anxious of any group except the workshop participants; however the male elementary education majors scored the lowest for math anxiety. Because females make up the majority of elementary school teachers, Kelly and Tomhave (1985) conclude that elementary teachers may be passing on their own anxiety about mathematics to the girls in their classroom. They hypothesize that students surrounded by confident, enthusiastic, and sensitive teachers, familiar with a variety of strategies for teaching math, will be less susceptible to negative feeling about math than students whose teachers are anxious, negative, and uncomfortable with their own ability to teach and to learn mathematics (Kelly & Tomhave, 1985, p. 53).

Mathematics Anxiety

The majority of the research that has been done in this area has come under the heading of mathematics

anxiety. In many cases, investigators have focused on the "symptoms" of people who do not enjoy math or who cannot succeed academically in the subject. Counselors and educators have treated math anxiety as a unified construct, yet more thorough investigations have shown this not to be the case. There have been many studies which have investigated the attitudinal and personality variables which put one at risk for math anxiety. The following section will discuss some of these findings.

Definitions of Math Anxiety

In the Elementary School Journal, Reyes writes, "One of the difficulties with the mathematics anxiety literature is in understanding what mathematics anxiety is. It might be described as anxiety about mathematics, but to understand the description it is necessary to know what anxiety is" (1984, p.563). Webster's dictionary desribes anxiety as

> An abnormal and overwhelming sense of apprehension and fear often marked by physiological signs (as sweating, tension, and increased pulse), by doubt concerning the reality and nature of the threat, and by self-doubt about one's ability to cope with it.

There have been many definitions of math anxiety, some of which were discussed in Chapter One. The most

widely used is that of Richardson and Suinn (1972), in which math anxiety is described as "involving feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems" (p.551). Fennema and Sherman's (1976) definition is similar, if not more intense, "feeling of anxiety, dread, nervousness, and associated bodily symptoms related to doing mathematics" (p.4). Even Gough's 1954 work in the area had number anxiety as "the presence of a syndrome of emotional reactions to arithmetic and mathematics" (p. 344).

All of these definitions concentrate on physiological and emotional factors. However, as Webster's definition implies, there are cognitive factors involved as well. In fact, only the dictionary's definition of anxiety gives a clue to why the feeling exists--doubt about one's capacity to cope with a threat. One can infer that if there were no questions about an individual's ability to deal with a threatening situation he or she would not have the feeling of being overwhelmed.

One of the major problems with the literature on math anxiety is that definitions are descriptive rather than causal. When students avoid math, do poorly in the

subject, or even feel physically uneasy about the prospect of facing problem solving, researchers have called them "math anxious"; however this label gives us few clues as to the causes of these behaviors.

Frary and Ling (1983) conducted a study hypothesizing that mathematics attitudes might be the result of some other stable personality measures. Results of the factor analyses showed that the most significant factor represented four of the five math attitude scales as well as a moderate loading of test anxiety. Because the math anxiety attitude scale had a loading of .89, they designated this factor as "mathematics anxiety." Finding little or no relationship between the personality measures and math anxiety, led them to conclude that "mathematics anxiety is relatively superficial, perhaps responsive to simple persuasion or desensitization" (Frary & Ling, 1983, p. 990).

Relationships between state, trait, and test anxiety

Reyes (1984) suggests that math anxiety be viewed within the context of the literature on anxiety as a general psychological construct. One of the most significant theories of anxiety was put forth by Spielberger (1972) who divided the construct into state

and trait anxiety. State anxiety is defined as an unpleasant emotional state or condition which is characterized by activation or arousal of the autonomic nervous system (p. 482). This type of anxiety is linked to specific times and situations and is evident when a person feels threatened by a certain place or event. Trait anxiety, however, is viewed by Spielberger as a relatively permanent personality trait which the person experiences across situations.

More recently, Byrd (1982, cited in Reyes, 1984) presented a model of how a person reacts to an anxiety-provoking situation. The individual meets with a situation which she or he must experience as threatening. The threat may produce physiological reactions which are not easily controlled; however behavioral reactions (nail biting, eating, etc.) are more subject to conscious control. During a period of cognitive reappraisal, the person decides how to cope with the stressor. Some anxiety might actually improve performance (facilitative anxiety) while more often the anxiety hinders performance (debilitative anxiety).

In the case of mathematicics, any situation involving mathematical computations might be perceived as a threat and individuals may choose to cope with the

threat by avoiding the task or rationalizing that it is not worthwhile. Of course, they could also choose to study harder or to get assistance with the problem, although this happens less frequently!

There have been many questions concerning the differences between mathematics anxiety and test anxiety. Wine (1971) has described the person suffering from test anxiety as focusing on the self and concomitant physiological reactions to the detriment of the task performance. Test anxiety is almost always debilitative because of the individual's lack of attention to the task. Both Wine (1971) and Liebert and Morris (1967) have identified two components of test anxiety: worry and emotionality. Morris and Liebert (1970) found that worry, the cognitive concern about performance, was negatively correlated with test performance. Emotionality, the arousal of the autonomic nervous system, was not significantly related to performance.

A number of studies have tried to uncover the relationship between general anxiety, test anxiety, and mathematics anxiety. Betz (1978) found a correlation of -.28 between scores on the Fennema-Sherman Math Anxiety Scale (MAS, Fennema & Sherman, 1976) and the A-trait

scale of the State-Trait Anxiety Inventory (STAI, Spielberger, Gorsuch, & Lushene, 1970) and -.42 between the MAS and the Test Anxiety Inventory (TAI, Spielberger, Gorsuch, Taylor, Algaze, & Anton, 1978 cited in Reyes, 1984; high anxiety on the MAS produces a low score; high anxiety on the STAI and TAI produces a high score).

Hendel (1980) uncovered a correlation of .65 between the MARS (Richardson & Suinn, 1972) and the Suinn Test Anxiety Battery (Suinn, 1969) for 69 adult women who had enrolled in a math anxiety reduction course. A regression analysis indicated that for these women, test anxiety was the most significant predictor of math anxiety.

Dew, Galassi, and Galassi (1983) asked 769 students at the University of North Carolina at Greensboro to complete a number of measures in order to untangle the relationship of math anxiety to test and general anxiety. Students filled out the MARS, the MAS, the Sandman Anxiety Toward Mathematics Scale (ATMS, Sandman, 1974, cited in Dew et al., 1983), and the STAI. All three of the math anxiety measures were moderately and more closely related to each other (37.2%-62.4%) than to measures of test anxiety

(11.6%-36.%). Dew et al. (1983) suggest that Hendel's findings may be due largely to his use of the MARS and the STABS, both of which were constructed by Suinn and which share items in common.

Finally, Dew et al. (1983) found that math anxiety was equally related to both the emotionality and worry component of test anxiety. Because worry is supposed to be the more stable component of test anxiety, it was expected that the correlation between worry and math anxiety would be greater than for emotionality. Dew et al. (1983) accepted this as further evidence that math anxiety and test anxiety are not identical constructs.

In 1984, Dew, Galassi, and Galassi further investigated the relationship between test, math, and general anxiety. Sixty-three undergraduates completed the measures listed in the description of their 1983 study, but in addition, students completed the emotionality and worry components of the Deffenbacher Post-Task Questionnaire and three mathematical problem sets. Students also had their heart rate, skin conductance, and skin fluctuations monitored.

As in the 1983 Dew et al. study, math anxiety measures were more closely related to each other than to test anxiety. The MARS appears to focus more on test

related math anxiety and situational worry than either the MAS or the ATMS. None of the math anxiety nor test anxiety measures accounted for variance in the students' problem set performance above and beyond a measure of math ability (SAT-M). However, the authors caution that the SAT-M is not a "pure" measure of innate math aptitude and could be influenced by years of previous anxiety and negative attitudes about math.

Physiological measures bore little relation to math anxiety; however this finding could have been the result of the confounding of assessment characteristics. This was also the case for avoidance. Dew et al. (1984) measured avoidance by the number of problems left uncompleted or completed out of order. They hypothesized that after individuals are forced to confront the anxiety-provoking situation, they demonstrate few avoidance behaviors. The authors recommended that avoidance of math problem solving <u>situations</u> would be a more appropriate criterion variable.

It would appear that although math anxiety and test anxiety share some common variance, no study has demonstrated a large enough correlation to dismiss math anxiety as purely a manifestation of test anxiety in

mathematical evaluation situations. However, neither construct is very useful unless it affects performance. Reyes (1984) cites a number of studies that have shown a relationship between high anxiety and low achievement (Aiken, 1970; 1976; Betz, 1978; Callahan & Glennon, 1975; Crosswhite, 1972; Sarason, Davidson, Lighthall, Waite, & Ruebush, 1960; Szetela, 1973). Frary and Ling (1983) found that students with higher levels of math anxiety tended to receive lower course grades, had lower grade point averages, and took fewer math courses.

Llabre and Suarez (1985) found that math anxiety was unable to contribute significantly to the prediction of algebra grades for college men and women after controlling for math aptitude. They acknowledge that the math component of the SAT is likely not a "pure" measure of aptitude and could be confounded with anxiety, a problem they say "plagues math anxiety research" (Llabre & Suarez, 1985, p. 286). They also found that math anxiety is less specific in men, sharing 24% of the variance with general anxiety, as opposed to 4% for women. The authors saw implications for treatment, recommending that women could more than

men interventions specifically designed for dealing with math situations more than men.

Reyes (1984) pointed out that the relationships between anxiety and performance have been correlational rather than causal. Interventions that have been able to reduce anxiety have not always been successful in improving performance, producing further questions about the power of anxiety to reduce performance directly (Reyes, 1984).

Ultimately, identifying "math anxiety" as a construct in its own right produces more questions than answers. One of the areas about which there has been the most controversy has been the differences in math anxiety and performance between men and women. The following section will discuss the research in this area.

Sex Differences in Mathematics Achievement, Attitudes, and Anxiety

In their much quoted book, The Psychology of Sex Differences, Maccoby and Jacklin (1974) were among the first to review the literature on the differences between boys' and girls' quantitative abilities. They noted that up until junior high there were few

differences, but that after age fourteen, boys' performance in mathematics was superior to girls'. In 1960, the Project TALENT studies reported no sex differences in math achievement for ninth graders, but by the senior year in high school, males did slightly better (Flanagan, Davis, Dailey, Shaycroft, Ori, Goldberg, & Neyman, 1964). Similar differences favoring males have been found in international studies and longitudinal studies done in the United States. Wilson (1972) showed that males excelled at higher cognitive tasks related to application and analysis but that women were superior on lower level cognitive tasks. The California Assessment Project (CAP, 1978) found no overall differences in math performance between the sexes in sixth grade, but found twelfth grade girls to be weaker than their male peers in measurement applications, geometry applications, and in probability and statistics. Gifted males and females have been found to perform differently on the quantitative section of the SAT when the test is taken in junior high. Fox and Cohn (1980) demonstrated that males scored higher than females during each of the six years they conducted their talent search.

Physiological Explanations of Sex Differences

There have been some attempts to explain these sex differences as the result of innate, physiological mechanisms. Some of these studies have involved the investigation of differences in spatial ability since it has been found to be related to math performance (Fennema & Sherman, 1977; Mellone, cited in Maccoby & Jacklin, 1974). Some of the hypotheses have included a recessive gene for spatial ability located on the X chromosome. The idea is that the chance of girls inheriting the two X-linked, recessive genes necessary for the trait to manifest itself is less than the the chance for boys inheriting the one recessive gene needed. Therefore, women tend to achieve less on tests of math and spatial ability (Stafford, cited in Maccoby & Jacklin, 1974). Studies by Bock and Kalikowski (cited in Boles, 1980), DeFries et al. (cited in Boles, 1980), and Fennema and Sherman (1978) have disputed this hypothesis.

Levy (1976) has advanced a hypothesis about spatial performance and hemispheric dominance, in which males are more similar to left handed males because their brain hemispheres are less specialized for verbal versus spatial-gestalt functioning. Levy tested

graduate and post-doctoral students using the WAIS Performance scale and a test of verbal reasoning and found that left-handed men did more poorly on the performance scale than on the verbal. Their performance IQ was significantly lower than the right handed males. Levy hypothesized that optimal intellectual functioning occurs when the right hemisphere is specialized for gestalt, spatial functioning. She believes that left handers have poorer spatial ability because they have a greater frequency of verbal functioning in both hemispheres (Levy, 1976).

Sherman (1977) found that although left-handedness was relatively detrimental to male spatial scores and beneficial to verbal performance, the reverse was true for females. Spatial scores of left-handers were never significantly lower than for right-handers within sex. There were no significant differences between boys and girls for math achievement in the ninth and tenth grades; however both left and right handed boys scored higher in math achievement in eleventh grade.

The Differential Coursework Hypothesis

Elizabeth Fennema and Julia Sherman challenged the assumption that males always achieve more highly than females. They hypothesized that sex differences were

caused by some third factor, namely the differing numbers of math courses taken by girls and boys. In addition, they suggested that courses involving spatial relations and outside activities that included both mathematics and spatial relations also contributed to scores on standardized tests of mathematics.

In 1977, Fennema and Sherman tested male and female students at four Wisconsin high schools. The cognitive variables assessed were math achievement, general/verbal ability, and spatial visualization. They also measured the following affective variables: attitude toward success in math, stereotyping math as a male domain, perceived attitudes of mother, father, and teacher toward the student as a learner of math, and perceived usefulness of math. Other variables examined were the number of courses with math prerequisites, out of school math activities, and courses and activities involving spatial skills.

Although females tended to score higher on measures of verbal ability, the differences were not significant. Males scored higher on the math achievement and spatial ability tests; however the differences were significant at only two schools. Boys tended to engage in more math activities outside of

school, to take more math-related courses after the ninth grade, and to take more courses requiring spatial ability, differences that were significant at two schools. At almost all of the schools, boys were more confident about their ability and rated math as more of a male domain.

At School 1, when scores of confidence in math ability, perceived attitudes of parents, perceptions of math as a male domain, and usefulness of math were used as covariates, the sex differences in math achievement became non-significant. At School 4, when both spatial visualization and the six significantly different affective variables were covaried out, achievement effects also became non-significant. When the numbers of math and spatial related courses were employed as covariates, differences in spatial visualization scores at Schools 2 and 4 disappeared.

DeWolf (1981) conducted a similar test of the differential coursework explanation of achievement differences on students from Washington state high schools. Students were juniors taking the Washington Pre-College Test (WPC) which included the following:

1) Quantitative Skills A--ability to determine whether enough information is given to solve a problem

2) Quantitative Skills B--ability to determine the relative size of the given qualities

3) Applied Mathematics--applying knowledge of arithmetic and elementary algebra to solve practical problems

4) Mathematics Achievement--knowledge of algebra and geometry

5) Spatial ability--ability to visualize transformations in three dimensions

6) Mechanical Reasoning--ability to understand physical principles as applied to mechanical devices

Each student's transcript provided the grades and the semester credits for total physics coursework and for math coursework divided into general math, algebra, geometry, and advanced mathematics. Mathematical electives such as accounting and business math were not included in the analysis.

Males scored significantly higher than females on all six WPC tests and took a significantly greater number of courses in algebra, geometry, advanced math, and physics. The only difference favoring females was in overall math grade point average. The multiple regression analysis showed that sex accounted for a significant amount of the variance in performance for Quantitative Skills B, applied mathematics, and mechanical reasoning.

When the amount of coursework in general math, algebra, geometry, advanced math, and physics was controlled, sex did not predict Quantitative Skills A and math achievement. Coursework alone accounted for the largest proportion of the variance of Mathematics Achievement (51%) and 29% of the variance of Quantitative Skills A. Spatial ability was uninfluenced by sex once math coursework was controlled; however Quantitative Skills B, Applied Mathematics, and Mechanical Reasoning remained subject to prediction by sex, regardless of the control exercised over coursework preparation.

Although not all differences can be attributed to differential patterns of coursework, DeWolf's findings support Fennema and Sherman's hypothesis that sex differences in math achievement are due in large part to environmental differences, rather than to innate physical factors. DeWolf hypothesizes that the sex differences that remain in her study could be due to bias in item content and inadequate control for other coursework that may teach math and spatial skills.

Two researchers who have held firm to the idea that boys have a greater tendency to excel in math than girls are Camilla Benbow and Julian Stanley of Johns

Hopkins University. In their studies of gifted junior high students who took the SAT they found that by age thirteen, the gap between boys and girls begins to widen significantly, especially in the higher end of the score distribution where boys outnumbered girls 13:1 in scores over 700. Benbow and Stanley (1983) stated that because boys and girls were matched for age, intellectual ability, grade, and number of math courses, differences could not be due to sex bias or differential course taking.

Senk and Usiskin, in a less publicized article (1983), offered an explanation for these differences. They administered a group of geometry tests to students in five states chosen to represent a cross section of educational, socio-economic, and ethnic backgrounds. Students were given a 25 minute test for their entering knowledge of geometry at the beginning of the school year (EG) and a geometry proof test and a multiple choice geometry achievement test (CAP) at the conclusion of the year.

The three forms of the proof test were not equivalent in difficulty so the results are reported separately. Raw mean total correct were higher for males on two forms and for females on one form, but

none of these differences were significant. Mean scores for girls on the test of entering geometry were significantly lower than the scores for boys. When EG scores were used as variables in computing proof test total scores, girls scored higher than boys on each form and significantly higher on form three. Therefore, even though females begin their high school geometry course with less knowledge than do males, at the end of the year there are no consistent differences on the solving of geometry proofs. Senk and Usiskin (1983) find these results particularly striking because boys scored significantly higher on the geometry achievement test.

In response to Benbow and Stanley (1980), Senk and Usiskin (1983) studied subsets of high performing students. Of the 71 students who had perfect or nearly perfect scores on any one of the three proof test forms, 37 were female and 31 were male. The second subset consisted of 12 girls and 7 boys who were in the seventh and eighth grades, and had thus accelerated at least two years. There were no sex differences on the proof test, either adjusted or unadjusted. The third subset consisted of students who scored in the top 3% on the CAP, comparable to the Benbow and Stanley

requirement that students score in the top 3% on a standardized measure of math achievement. In this case, there were 58 males and 31 females, with significantly more males than females scoring at the upper end of the test. These results are similar to Benbow and Stanley (1980; 1983) only on the multiple choice CAP test; there were no sex differences for the proof test.

Senk and Usiskin (1983) conclude that "the more an instrument directly measures a student's formal educational experiences in mathematics, the less the likelihood of sex differences" (p. 9). Because the large sex differences in the Benbow and Stanley studies occur only on tests in which the items are designed to be unfamiliar to students, Senk and Usiskin suggest that scores could easily be affected by experiences outside of formal math instruction such as math contests, computer use, and outside reading, all of which claim more male participants (Senk & Usiskin, 1983). Because geometry proof writing is rarely encountered outside the classroom, boys and girls are more likely to have had equal exposure both inside and outside of the classroom.

Sex Differences in Math Anxiety

Sex differences in math anxiety have also been reported, often as a cause of sex differences in math performance (Ernest, 1976; Sells, 1973; Tobias, 1976). Dew et al. (1983) found that women had significantly higher scores on the MARS and the MAS but not on the ATMS. However, women scored higher on the other measures of trait and test anxiety as well, suggesting that women's tendency to report emotions more often than men may be a factor here. Resnick et al. (1982) found no significant sex differences on the MARS and suggest that studies that have found differences may be focusing on a unique group of women who have been away from formal math instruction for a long time (Rounds & Hendel, 1980).

Once again, math anxiety emerges as a construct with little ability to predict behavior and academic performance. When Tobias (1976) first discussed math anxiety, she viewed it as an explanation for the underrepresentation of women in math courses and math careers. Although she does discuss the various ways in which women are discouraged from pursuing math courses and careers, it is not clear that these factors are causing women to be *anxious* about math.

Negative Influences on Women's Participation in Math

At the same time that researchers find that the gap in math achievement is widening for girls and boys, males also begin to exhibit a greater interest in pursuing mathematics coursework. Brush (1980) found that boys show a significantly greater desire than do girls to take high school math, and Fox (1980) discovered that even when girls and boys do not differ in their intentions to study higher level math, the actual female enrollment in calculus is significantly less than for males. This underenrollment takes its toll on the numbers of women who pursue careers in math.

Teacher influences

There are a number of environmental factors that may conspire to dissuade women from enrolling in math courses. As has been previously stated, the numbers of female elementary teachers who dislike math are large. These women may unintentionally encourage their admiring female pupils to emulate them by avoiding math (Kogelman & Warren, 1978). Teachers have also been found to devote more attention to developing math skills in boys as early as the second grade (Fox, 1980). Boys are more often called upon, spoken to, and

asked questions than are girls (Becker, 1981; Skolnick, Langbort, & Day, 1982).

Teachers and counselors encourage young women to pursue future math study and careers far less often than they do boys (Ernest, 1976). Luchins and Luchins (1980) interviewed women and men who had chosen careers in math, and found that 24% of the former recalled being discouraged by high school teachers as compared with 2% of the latter. Frazier and Sadker (1973) found that over 75% of teachers' criticisms of boys pertain to improper conduct or problems with neatness, while almost all of the praise they receive is for intellectual and academic achievement. For girls, however, the process is reversed; they are praised for neatness and obeying the rules and criticized for their lack of academic achievement.

A common message sent to boys is "you will succeed if you just settle down and try" (Skolnick et al., 1982). When boys fail, teachers attribute their performance to lack of effort six times more often than they do for girls (Dweck, Davidson, Nelson, and Enna, 1978). Boys are then encouraged to try again, while girls are praised merely for trying at all. In this way, girls are taught to be compliant and rigid and to

refrain from being creative, autonomous, and analytic, skills essential to the study of mathematics (Frazier & Sadker, 1973).

Family influences

Many of the same problems of lack of encouragment and lowered expectations for girls' success in mathematics arise in the home. Skolnick et al. (1982) see the beginning of a cycle of math anxiety and avoidance with mothers of daughters. Ernest (1976) found that after grade six, both boys and girls tend to seek help with their math homework from their fathers. Both parents generally agree that the father is the "math expert."

Armstrong (cited in Fox, 1980) found that fathers' educational expectations for their daughters were the most significant predictors of girls' math enrollment. Unfortunately, most fathers do not expect their daughters to perform as well as their sons in math (Ernest, 1976; Fox, 1980; Hilton & Berglund, 1974). In interviews with highly creative mathematicians, most women were seen as being highly identified with their fathers.

Women who have pursued careers in math are likely to have no brothers or to be only children (Helson,

1971). Given that fathers are usually the parent to whom children turn for expertise in math, this is not surprising. If fathers expect their daughters and sons to follow in the footsteps of the same sex parent, only sons would be encouraged or expected to pursue math. However, if there are no sons, fathers who believe math to be important will have only their daughters to encourage.

Role strain

Apart from the lack of encouragement and guidance young women receive, they also face conflicts in terms of sex role expectations from their peers. As was mentioned above (Brush, 1980) the common characteristics associated with success in mathematics are viewed as masculine traits. For an adolescent female hoping to be accepted by male peers, excelling in math is not the key to success. Young women who are particularly good in math have reported that their peers consider them strange and that they have been advised to follow more "traditional" female career paths so that they do not alienate themselves from men (Luchins & Luchins, 1980).

To avoid becoming social outcasts, young women will often reduce this role strain by "playing dumb."

Sherman (1982) interviewed young women who had taken four years of math in high school. Although only 17% admitted to feigning ignorance in situations where they could have provided expertise, 76% accused other young women of "playing dumb!"

This phenomenon has been documented in girls as young as ten-years-old. Steinkamp and Maehr (1984) reported that when asked about their desire to take courses in science, girls were less likely to show high motivation when a male "visitor" was present, when questions were administered orally, or in a small group situation. The authors concluded that the girls were reluctant to demonstrate interest because they were aware of the masculine image of scientific study (Steinkamp & Maehr, 1984). Luchins and Luchins (1980) found that women mathematicians explain the paucity of females in the field as the result of the pervasive attitude that math is a male domain. Male mathematicians explain the lack of women mathematicians as due to women's lack of interest and inability to think mathematically.

Hollinger (1985) has demonstrated the effects of stereotypes on the career patterns of mathematically talented women. Starting with research that has shown

the importance of self-perceptions of math ability on success in math (Meece, Parsons, Kaczala, Goff, & Futterman, 1982), Hollinger set out to uncover differences in self-perceptions of math ability in women aspiring to careers requiring differing levels of mathematical and scientific knowledge.

Hollinger (1985) divided women into six career-track categories: non-traditional math, non-traditional science, neutral/traditional math/science, nontraditional non-math, neutral non-math, and traditional non-math. The three non-math categories were combined since they did not differ significantly. The analyses of variance indicated that the four career aspiration groups differed on the following self-perceptions of career relevant abilities: mechanical ability, manual ability, friendliness, math ability, artistic ability, and science ability. These findings supported Hollinger's (1985) hypothesis that the self-perceptions of <u>multiple</u> abilities rather than just that of math ability distinguishes non-traditional math career aspirants from all other career groups.

The non-traditional math career group had significantly higher self-perceptions of math ability

than the non-math career group. Interestingly, the non-traditional math group also demonstrated significantly lower self-perceptions of friendliness and artistic ability than the other three groups. The non-traditional science career aspirants reported significantly higher estimates of math, mechanical, and manual and science ability than the non-math groups but not greater than the neutral/traditional math/science groups. The only way in which the neutral/traditional science career aspirants were different from the non-math group was that the former reported higher self-estimates of science ability. Hollinger (1985) concludes that adolescents see their level of math ability as a "threshold variable" and believe that the level of competence in math required for neutral or traditionally female math and science careers is lower than for non-traditional math and science careers.

Hollinger's (1985) findings support previously discussed results regarding stereotypes of mathematicians. The low estimate of friendliness reported only by the non-traditional math career group "may reflect the influence of the stereotyped perception of the mathematician as social isolate and is consistent with findings indicating that women

mathematicians and women in non-traditional career fields may be more aloof than other women" (Hollinger, 1985, p. 333). Another finding that supports the notion of adolescent stereotypes is the low self-estimate of creative ability demonstrated by the non-traditional math group. This is a disturbing finding for those who recognize the importance of creativity in mathematics.

Forbes (1985) sampled undergraduate women who had declared either a non-traditional math/science major or a traditional non-math/science major. When asked to respond to questions about how their lives would be affected as a result of pursuing a variety of math/science and non-math science careers, both groups experienced greater conflict when they imagined themselves pursuing math/science careers as compared with non-math/science careers. The greatest confict centered around the amount of time the women expected that they would be able to spend with their family. This effect was even stronger for the math/science career aspirants. Sherman (1982) revealed a similar finding. Young women who had taken four years of high school math were more likely to worry about balancing a family and career than were women who had taken fewer years of math.

Summary

A great deal of the research on mathematics achievement and avoidance has focused on sex differences and the possible causes for women's underrepresentation in math courses and careers. Despite the fact that fewer young women than young men are becoming interested in mathematics and the sciences, the numbers of young men expressing interest in these areas is still alarmingly small.

There are unique problems faced by young women, however. Not only do they face the same problems of curriculum and teaching strategies as do boys, but they also experience outright discouragement from significant adults and peers. One of the central themes of this review has been the prevalence of the stereotypes about mathematicians as socially inept, uncreative, unemotional, logical, and isolated. While these are not wholly pleasant qualities with which men might wish to be associated, they run counter to the traditional views of femininity to an even greater degree.

Women seem to be under the impression that to pursue a career in math and science will prevent them from having a family life. It is not clear whether

women feel that they will literally not have time for their family because of the demands of a math or science career or that becoming a mathematician will make them unattractive to potential partners. There is indirect evidence that supports the latter. Rotter (1982) showed that women engineers were seen as uninterested in dating and lacking in social skills. Hollinger's (1985) study demonstrated that the women who aspired to math careers believed themselves to be less friendly and Helson's (1971) women mathematicians saw themselves as more aloof.

Boys are expected to do well in math by parents, teachers, and counselors. They are given the opportunity to experiment with mathematics and science outside of the classroom. They are even supposed to possess the personality and mental characteristics believed to be necessary to be a successful mathematician. Girls, however, have none of these positive expectations and in fact, often experience serious sex-role conflict if they are interested in and talented in mathematics. There are very few, if any, factors that can be relied upon to promote girls' interest and participation in math and science.

But to focus exclusively on women and the environmental factors which dissuade them from these careers is to deny that boys are also seeking to avoid math/science courses and careers. It is easy to make a case for girls lack of participation, it is disturbing that with all the positive expectations and training they receive that boys still feel uncomfortable about mathematics. An explanation must be proposed that encompasses both the sex-role socialization literature and account for the avoidance and anxiety demonstrated by males.

The Effect of Self-Efficacy Expectations on Human Behavior

The mechanism of self-efficacy has been developed by Albert Bandura to account for a wide variety of behavioral phenomena including coping behavior, physiological stress reactions, reaction to failure expectations, the development of intrinsic motivation, career aspirations, and even math "anxiety" and avoidance (Bandura, 1982). The following section will describe Bandura's theory of self-efficacy in human behavior, discuss the research that supports and disputes the theory, and finally, posit it as an explanatory mechanism for the widespread avoidance of

the avoidance of mathematics and the anxiety that accompanies this avoidance.

Explication of the Theory

> Knowledge, transformational operations, and component skills are necessary but insufficient for accomplished performances. Indeed, people often do not behave optimally, even though they know full well what to do. (Bandura, 1982, p. 122)

Bandura's main interest is in how people come to judge their own abilities and how these self-perceptions affect behavior. "Perceived self-efficacy is concerned with judgments of how well one can execute courses of action required to deal with prospective situations" (Bandura, 1982, p.122). Individuals are constantly being called upon to make decisions about their ability to cope with the world. Self-efficacy beliefs are not trivial; attempting a task without the requisite skills can be dangerous or even fatal, in some cases.

Bandura (1977a) has shown that in general, people avoid activities at which they know they cannot perform well and engage in those about which they feel confident. The degree of self-efficacy is also related to the amount of effort expended and persistence in the

face of obstacles. People who have doubts about their ability to cope will decrease their energy levels and will often give up altogether, while those who firmly believe in their ability will perservere and generally perform at high levels.

People develop their judgments about self-efficacy using four basic sources of information: 1) performance attainments, 2) vicarious experiences of observing the performances of others, 3) verbal persuasion and allied types of social influences that one possesses certain capabilities, and 4) physiological states from which people partly judge their capability, strength, and vulnerability (Bandura, 1982, p. 126).

Performance attainments, according to Bandura (1982) are the most influential source of information. Individuals can see firsthand whether they can or cannot cope with a situation or task. Obviously, successful experiences increase self-efficacy while failure experiences lower it. The latter is the case especially if the actor is expending adequate effort and there are no negative environmental influences.

However, individuals cannot possibly "learn by doing" for every possible circumstance. They must rely on vicarious experiences as well. Brown and Inouye

(1978) showed that when a person sees someone whom he or she believes to be of similar competence succeed, he or she will raise his or her self-efficacy expectations accordingly. However, when the model fails despite trying hard, the observer lowers his or her efficacy expectations. Besides giving social comparison information, modeling can also provide facts about the environment and its predictability and can teach observers coping strategies for use when dealing with difficult situations.

The third source of information for efficacy expectations is verbal persuasion, used to influence individuals to believe they have the requisite skills to achieve their goals. Chambliss and Murray (1979) have shown that verbal persuasion is especially effective when an individual has at least a minimal belief in her or his ability to successfully complete a task. Bandura has stated that verbal persuasion boosts self-efficacy enough that a person expends the effort needed to succeed. It can also promote the development of skills and a more permanent sense of personal efficacy. Finally, individuals also look to their physiological state for information about their abilities. When people experience physical signs of

stress they will often interpret this as a sign of weakness and vulnerability to failure.

However, Bandura posits that none of these four sources of information is important on its own; they become so only after coming under the influence of cognitive appraisal.

> The cognitive processing of efficacy information concerns the types of cues people have learned to use as indicators of personal efficacy and the inference rules they employ for integrating efficacy information from different sources. The aim of a comprehensive theory is to provide a unifying conceptual framework that can encompass diverse modes of influence known to alter behavior. In any given activity, skills and self-beliefs that ensure optimal use of capabilities are required for successful functioning. If self-efficacy is lacking, people tend to behave ineffectually, even though they know what to do. Social learning theory postulates a common mechanism of behavioral change-different modes of influence alter coping behavior partly by creating and strengthening self-percepts of efficacy. (Bandura, 1982, p.127)

Bandura and his associates have conducted a number of experiments designed to test this theory, many of which have used snake phobia as the behavior to be changed (Bandura & Adams, 1977; Bandura, Adams, & Beyer, 1977; Bandura, Adams, Hardy, & Howells, 1980). This disorder was chosen because of the minimal chance that subjects would encounter snakes outside of the

experimental session, thus confounding the results of the study. Persons are subjected to a number of different treatment strategies. Those in the "enactive mastery" group are gradually exposed to the fearful situation with the assistance of "induction aids." After these aids are withdrawn, subjects undergo experiences where they confront their fears to verify and then to generalize their efficacy.

In the vicarious treatment mode, subjects merely observe a model performing increasingly more threatening tasks without negative effects. The third treatment modality involves the subject's imagination. The assignments include the generation of images of multiple models successfully coping with and mastering the activity around which the phobia centers.

The results of these studies show that each mode of influence can raise and strengthen self-efficacy expectations. More importantly, behavior is closely tied to the amount of change in the perception of efficacy; the greater the level of perceived efficacy, the greater the level of performance. Self-efficacy also predicts perserverence, with high efficacy related to greater persistence. Enactive mastery appears to

produce the greatest and most generalized increases in coping, followed by vicarious and cognitive methods.

Self-efficacy is not merely a reflection of past behavior. Bandura and his colleagues have shown that some subjects do not increase self-efficacy until the final mastery task even though they have coped successfully with all of the tasks along the progression. Some subjects increase their self-efficacy expectations at much higher rates than their performance would have predicted. Bandura (1982) states that individuals are more influenced by their perceptions of their successes and failures than by the fact that they have succeeded or failed. Therefore, self-efficacy is a better predictor of subsequent behavior than previous behavior.

There have been a number of studies (Bandura & Adams, 1977; DiClemente, 1981; Kendrick, Craig, Lawson, & Davidson, cited in Bandura, 1982; McIntyre, Mermelstein, & Lichtenstein, cited in Bandura, 1982) which have shown that perceived self-efficacy is a better predictor of future performance than past performance. Bandura explains this as follows: initially people increase their perception of their abilities when their experience runs contrary to their

negative expectations or when they first gain new skills to cope with the feared activity. Individuals retain their weak self-perceptions while they continue to test their new knowledge and skills. If they encounter anything which shakes their confidence they will register a decline in self-efficacy despite their previous successes. After they become assured of their ability to predict and to cope with the threat, they become quite self-assured about their ability to manage future challenges.

An even more exacting test of the causal relationship between self-efficacy and action was carried out using vicariously induced levels of self-efficacy (Bandura, Reece, Adams, cited in Bandura, 1982). Subjects executed none of the coping strategies but merely observed others. The models emphasized predictability and controllability in their displays. The former was demonstrated by repeatedly showing how the feared objects were likely to behave across situations. The latter was exemplified by the model's use of highly effective techniques to manage the threat in many circumstances. Subjects' self-efficacy expectations were assessed at different points until they reached predesignated low or medium levels. When

later asked to perform the threatening task, those with higher levels of self-efficacy gained merely from observing models produced higher performance attainments.

In summary, self-efficacy expectations appear to mediate behavior and behavior change. Just because the individual is physically or mentally capable of performing a task does not mean that he or she will in fact be able to execute it successfully. Even successful previous performances do not always affect self-efficacy immediately. The degree to which persons will raise or lower their beliefs about personal efficacy depends upon such factors as task difficulty, effort expended, outside help received, situational circumstances, and the pattern or their successes and failure over time (Bandura et al, 1980).

Physiological Arousal

Self-efficacy theory explains the relationship between anxiety and cognitions and accounts for some of the failures of behavioral theory and therapy to alter anxiety reactions. According to behavioral conditioning principles, formerly neutral stimuli become associated with fearful experiences, thus generating anxiety long after the association has occurred.

The social learning perspective holds that it is an individual's _perceived_ inefficacy in coping with potentially threatening events that makes them anxiety-provoking. When one can alter these events to prevent, end, or ameliorate them, fear dissipates. When coping efficacy is increased, anxiety should diminish.

For Bandura, the cognitive component of negative arousal is more important than the actual physical discomfort produced by the aversive stimulus. People who believe themselves to be inefficacious focus on their inability to cope and see many situations as potentially threatening. They may increase the threat disproportionately, and they tend to worry about difficulties that are unlikely to arise. Where in some cases anticipating threatening situations can lead to the development of coping strategies, with these individuals, their arousal can inhibit any cognitions other than those of anxiety about the impending aversive situation. Bandura (1982) cites Beck, Laude, and Bohnert (1974) who found that fearful cognitions occur just prior to the onset of anxiety attacks in almost every case. The focus of these thoughts centers around deep fears about the ability to cope.

A number of studies have shown the relationship between fear arousal and self-efficacy (Bandura & Adams, 1977; Bandura et al., 1977; Bandura et al., 1980). In each of these studies, the methodology involved subjects undergoing different forms of treatment and then reporting the strength of their self-efficacy expectations regarding the performance of various tasks. Later, during behavioral testing, subjects reported their level of fear before and during the performance of the feared activity.

The results of these studies indicate that individuals experience high anxiety before and during the performance of tasks when they believe themselves to be inefficacious. As their self-efficacy increases, their fear arousal declines. When self-efficacy is at its highest point, the previously threatening tasks are completed with barely a trace of arousal.

Self-efficacy theory gives an alternative explanation for the results achieved by systematic desensitization. This approach is based on the dual-process theory that anxiety promotes defensive behavior which is in turn reinforced by the reduction of the anxiety produced by the occurrence of the conditioned aversive stimulus. The idea behind

systematic desensitization is to eliminate avoidance behavior by eradicating the "underlying anxiety" driving it. This is done by gradually increasing the proximity of the stimulus while simultaneously relaxing the subject. The association between the neutral stimulus and fear is replaced by one between the stimulus and relaxation.

That systematic desensitization produces behavioral changes is not disputed, the assumption that they come about because of the reduction of anxiety, is. Bandura (1977b; 1986) and social learning theorists view anxiety and avoidance behavior as coeffects rather than as causes. "Aversive experiences, of either a personal or vicarious sort, create expectations of injurious consequences that can activate both fear and defensive behavior. Being coeffects there is no fixed relationship between autonomic arousal and actions" (Bandura & Adams, 1977, p.289).

It is true that stressful situations foster emotional arousal that may provide data that impinge on personal commpetency. High levels of arousal are likely to impede successful performance, so it is reasonable for individuals to assume that they will perform less well if they are experiencing fear arousal. Approaches

such as systematic desensitization which focus on minute changes in physiological arousal reinforce this association. From the social learning perspective, reducing aversive arousal improves performance because it is raising efficacy expectations; the theory emphasizes the information gained from self-monitoring of physical states rather than the physical energizing properties. Because physiological arousal is only one source of information about self-efficacy, it rarely provides enough to eliminate avoidance behavior.

Bandura and Adams (1977) concede that when subjects visualize feared situations in systematic desensitization, there is bound to be some loss of extinction effects when they actually perform the feared behavior. However, they point out that since anxiety arousal to the imagined stimuli is eliminated in all subjects, dual-process theory cannot explain the variability in the performance of subjects who have all been equally desensitized.

To test the hypothesis that it is efficacy expectations rather than anxiety reduction that are changing behvior, Bandura and Adams (1977) administered standard systematic desensitization treatments to chronic snake phobics until their fear was completely

extinguished. The approach behavior and efficacy expectations of the subjects were measured before and after the treatment. Phobics have differing experiences regarding the stimuli they fear and are also likely to perceive their fear in differing ways. Bandura and Adams (1977) hypothesized that by eliminating arousal, self-efficacy would be enhanced but in differing degrees across subjects. They also predicted that the greater the efficacy expectations, the greater the reductions in avoidance behavior.

The comparison of pre- and post treatment efficacy expectations taken before the posttest confirmed that systematic desensitization significantly raises self-efficacy expectations for stimuli similar and dissimilar to those used in treatment (in this case, two different kinds of snakes), but to differing degrees. The higher the level of perceived efficacy at the end of treatment, the higher the level of approach behavior. Microanalytic analyses where subjects' abilities to predict their behavior on specific tasks showed an 85% congruence for the similar snake and an 82% congruence for the dissimilar snake. Furthermore, the higher the subject's level of self-efficacy following treatment, the lower his or her anticipatory

arousal at the prospect of performing the previously avoided task and the weaker his or her arousal during the actual performance. Bandura and Adams (1977) conclude that because thoroughly desensitized subjects ranged from 10% to 100% in the completion of the behavioral tasks, the knowledge of complete extinction is of little value in computing behavioral change. Measurements of self-efficacy appear to be much more accurate predictors of performance.

Self-Efficacy Theory and Math Avoidance

Recently, researchers have been using self-efficacy theory to understand academic and career decision-making behaviors (Betz & Hackett, 1981; Betz & Hackett, 1983; Hackett, 1985; Taylor & Betz, 1983). The results of these studies hold promise for understanding math avoidance behavior, most notably in women. Betz and Hackett (1981) asked 124 female and 101 male undergraduates to indicate how sure they were that they could fulfill the educational requirements and job capabilities for each of ten traditionally female and ten traditionally male occupations. They were also asked how interested and how seriously they would consider each career. American College Test math and English scores were also collected for each subject.

Overall, students believed the educational requirements for physicians, engineers, and mathematicians to be the most difficult, with 45%, 47%, and 49% of the students believing themselves to be capable of completing the academic prerequisites. The careers perceived to have the easiest educational requirements were elementary school teacher (88%), social worker (87%), and travel agent (85%).

Sex related differences were found for 10 of 20 occupations. Males demonstrated higher self-efficacy for accountant, drafter, engineer, highway patrol officer and mathematician, whereas females felt more capable than men of becoming dental hygienists, elementary school teachers, home economists, physical therapists, and secretaries. Males perceived the educational requirements for becoming a physician as most difficult, females believed engineering requirements to be the most rigorous. The greatest divergence of self-efficacy occurred for engineering with 70% of the men believing they could complete the requirements as opposed to 30% of the women.

Males and females also differed in their self-efficacy expectations regarding the completion of job duties. Males reported significantly higher

self-efficacy for the job duties of accountants, drafters, engineers, highway patrol officers, and mathematicians. Females had greater confidence in their ability to perform the duties of a dental hygienist, home economist, secretary, and social worker. Males believed the job duties of an art teacher to be the most difficult while females saw an engineer's duties as the most demanding.

The data show that the sex differences were due largely to females' low self-efficacy in regard to non-traditional female careers. Males believed themselves to be able to complete the educational requirements of an average of 6.9 of the 10 traditional (for females) careers and 6.9 of the 10 non-traditional (for females) careers and the job requirements of 7 of the 10 traditional occupations and 7.2 of the 10 non-traditional occupations. In contrast, females believed themselves to be able to complete the educational requirements of 8 out of 10 traditional careers but only 5.7 of the 10 non-traditional careers, and the job duties of 8 traditional careers and 6 non-traditional careers.

A stepwise multiple regression analysis was performed for the total group of students and for males

and females to examine the relationships between self-efficacy expectations, interests, and sex with perceived range of career options. First of all, females said they would consider more traditional careers than males (6.3 vs. 2.4) whereas males reported considering more non-traditional careers (4.4 vs. 2.6). Thus, the sex differences in range of career options closely resemble those for self-efficacy expectations. The multiple regression further confirms these findings.

Interests for both non-traditional and traditional careers were the major predictors of the range of traditional career options. The degree of interest in traditional occupations was positively related to the range of traditional options, but interest in non-traditional careers was negatively related to consideration of traditional options. Non-traditional interests and non-traditional efficacy were positively related to the range of non-traditional career options considered by both females and males, and self-efficacy, in terms of traditional occupations, was negatively correlated with the range of non-traditional career options considered by the students. Sex was a significant predictor for the total group analysis,

with males considering non-traditional options more frequently than women (Betz & Hackett, 1981).

Intercorrelations among the variables show that the range of traditional options most strongly correlated with traditional interests (.63), traditional self-efficacy (.29), and sex (-.24). For non-traditional career options, the highest correlations were between non-traditional interests (.63), non-traditional self-efficacy (.46), and sex (.44).

Traditional interests and traditional self-efficacy were moderately correlated (.38), as were non-traditional interests and non-traditional self-efficacy (.42). Thus the two best predictors of the range of both types of career options were also moderately correlated. To explore this relationship further, Betz and Hackett (1981) conducted stepwise regression analyses with non-traditional and traditional interests as the dependent variables. In the prediction of traditional interests, traditional self-efficacy was positively related to expressed interest for both sexes. For females and all students combined, non-traditional self-efficacy was negatively related to traditional interests. Non-traditional

interests were positively related to non-traditional self-efficacy and for females and the total group, negatively related to traditional self-efficacy. Gender was a significant predictor for the total group, with females expressing a greater interest in traditional occupations and males in non-traditional careers (Betz & Hackett, 1981, p.406).

Finally, measures of ability (ACT scores) were examined for their relationship to the other variables in the study. Neither English nor math scores were significant predictors of career options. There were also no significant differences between the sexes for either subscale score, though the relationship between self-efficacy and ability differs for males and females. For women, ACT math and English scores were moderately related to the <u>level</u> of self-efficacy for traditional and non-traditional occupations; for men, the moderate correlation existed for both level and <u>strength</u> of non-traditional and traditional self-efficacy. ACT scores were not significantly correlated with females' perceived range of career options, but math ACT scores were significantly and positively related to males' perceived range of

non-traditional career options and negatively related to their perceived range of traditional options.

In summary, young men and women differ in their perceptions of their ability to succeed in non-traditional and traditional careers along traditionally sex-typed lines. Most of the difference is due to females' lowered efficacy in regard to traditionally male fields, but only certain non-traditional careers. Even though women are underrepresented among physicians and lawyers, they did not have significantly lower self-efficacy expectations in these careers than did men. The careers which emphasized mathematics, such as accountant, engineer, and mathematician were consistently rated as most difficult by females. Self-efficacy expectations were important predictors of the range of career options considered and the degree of interest in these jobs for both sexes.

Betz and Hackett (1981) draw important conclusions for future research, especially in the area of women's career development. Because the results show an imperfect relationship between ability and perception of ability, students may be eliminating careers in which they _could_ succeed because they _think_ they cannot

succeed. In fact, low self-efficacy may prevent students from developing interests and basic skills and training needed for later study. Betz and Hackett (1981) reiterate the findings of previous researchers:

> ...Women's lower self-efficacy expectations with regard to occupations requiring competence in math may be due to a lack of experiences or successful accomplishments, a lack of opportunities to observe women competent in math, and/or a lack of encouragement from teachers or parents. Interventions based on Bandura's (1977) model could be directed at increasing perceptions of self-efficacy and as a possible consequence increasing the range of career options from which the individual could choose (Betz & Hackett, 1981, p.409).

In 1983, Betz and Hackett teamed up again to explore further the role of mathematics self-efficacy expectations in career and academic decision-making. They hypothesized that 1) college males have greater self-efficacy expectations in mathematics than college females and 2) math self-efficacy expectations are an important factor in career decision making, especially in the selection of science-based majors. Additionally, Betz and Hackett (1983) investigated the relationship among math self-efficacy, math anxiety, sex roles, and attitudes toward mathematics.

The authors developed a Mathematics Self-Efficacy Scale (MSES, Betz & Hackett, 1983) which covered three domains of math related behaviors in its three subscales. Math self-efficacy was judged to include "perceptions of performance capability in relationship to math problems, everyday math tasks, and mathematics-related college coursework" (Betz & Hackett, 1983, p. 332). The scale was refined from 75 items to 52, and students reported their self-perceptions of ability using a 10-point scale ranging from "no confidence" to "complete confidence" in their ability to complete a specific task or problem or to receive a grade of B or better in a math-related course. Mathematics attitudes were assessed using Betz's 1978 revision of the Fennema-Sherman Mathematics Attitude Scales. Sex role orientation was assessed using the Bem Sex Role Inventory (BSRI, Bem, 1974). Finally, subjects' college major preferences were classified along a 5-point science-non-science continuum, with higher scores indicating greater emphasis on science (Goldman & Hewitt, 1976).

Males' self-efficacy expectations for each subscale were consistently higher than females'. For math tasks, males reported significantly stronger

self-efficacy on eight of the 18 items and scored higher, though not significantly so, on 7 of the remaining items. The only 3 items on which females scored higher than males, although not significantly, were on items related to making curtains, grocery shopping, and cooking.

On the college course subscale, males' self-efficacy expectations were significantly higher for 11 of the 16 courses and non-significantly greater for the remaining 5. Finally, for 5 of the 15 math problems, males reported significantly greater self-efficacy and on all of the problems males matched or exceeded females' self-efficacy expectations.

For total scores, males scored significantly higher on the 3 subscales of the MSES and on the total score. Males also had significantly more positive attitudes toward math, greater confidence in their ability, and a greater tendency to see math as useful. Females, however, reported a significantly higher belief that math was a male domain and had a tendency toward more math anxiety.

Correlations among the variables show that students with stronger math self-efficacy report lower levels of math anxiety, higher levels of overall

confidence and motivation, and a greater tendency to see math as useful. Also, stronger math self-efficacy is related to higher scores on the masculinity scale of the BSRI, though unrelated to the femininity scale.

The stepwise multiple regression using declared major as the independent variable, found sex, math self-efficacy, years of high school math, and math anxiety to be significant contributors to the prediction of science-based major. Subjects who had stronger math self-efficacy, more years of high school math, lower levels of math anxiety, and who were male were more likely to have chosen science-based college majors.

Betz and Hackett (1983) conclude that their data suggest math related <u>cognitions</u> may be at least or more important than actual math ability as measured by the ACT. Math ACT scores did not contribute unique variance to the regression equation. Low math self-efficacy expectations and the resulting avoidance of math-related coursework needed for science careers are suggested as particularly characteristic of females. "Thus math related cognitions are suggested both theoretically and empirically to be important

moderators of sex differences in major and career choice" (Betz & Hackett, 1983, p.343).

The finding that females had higher self-efficacy expectations on tasks related to traditionally female activities supports Bandura's claim that self-efficacy is learned through successful performance and vicarious learning. The authors suggest that mathematics curricula and treatments for math avoidance emphasize the use of math within traditionally female contexts so that women become aware of ways in which they use and are successful in mathematics.

Another important result of the above study is the support the data give to Bandura's (1977a) hypothesis that anxiety is an inverse "coeffect" of self-efficacy expectations. Math anxiety and total MSES scores were positively and moderately correlated (.56, higher MAS anxiety scores indicating greater math confidence) as were MSES scores and global math confidence (.66). MSES scores were also positively correlated with self-reported masculinity, (.33) supporting the finding (Spence & Helmreich, 1980) that higher levels of masculinity facilitate self-confidence or self-esteem.

Betz and Hackett (1983) suggest that treatment programs make use of an assessment device such as the

MSES so that individuals' specific needs can be assessed and dealt with in the treatment. Interventions should concentrate on raising efficacy expectations through performance accomplishments, vicarious learning, encouragement and support, and anxiety management.

Hackett (1985) used the technique of path analysis to develop and to refine a causal model of math-related major choice. The path analysis consists of 3 parts: 1) development of the causal scheme specifying the hypothesized causal relationships among the variables, 2) computation of path coefficients and the elimination of non-significant paths from the proposed model, and 3) the delineation of a reduced path model based on the resulting data. Based on self-efficacy theory and research on mathematics achievement and attitudes, the model tested was as follows: gender was hypothesized to influence all other variables directly and indirectly; sex role socialization, as measured by the BSRI Masculinity scale, was hypothesized to mediate some of the influence of gender which in turn would affect years of high school math, ACT scores, and math self-efficacy. Math self-efficacy was predicted to mediate these causally prior influences and then to

affect math anxiety and math-related major choice (Hackett, 1985, p. 50).

All of the correlations among the variables, with the exception of the masculinity score, were significant in relation to the math/science relatedness of major choice. Self-efficacy had the highest correlation with math-related major choice (.50). ACT math score, math anxiety, and years of high school math correlated most highly with math self-efficacy (.68, .58, .47, respectively), but correlations with all of the other variables were significant also. Masculinity scores were only significantly correlated with self-efficacy (.26) and gender (-.28), demonstrating that males were more likely to score higher on the BSRI-M and that higher BSRI-M scores were related to higher levels of math self-efficacy. ACT scores and years of high school math were, not surprisingly, significantly related (.46), but both variables were also strongly correlated with math self-efficacy and math anxiety.

To determine the causal ordering of these variables, path coefficients were computed through a series of multiple regressions. All path estimates of less than .10 were excluded from the model in order to

control for practical significance beyond statistical significance. The prediction equations for masculine sex role and years of high school math leave a great deal of the variance unexplained, however later equations explained a moderate to high amount of the variance. Gender and years of high school math adequately predict ACT scores (22%), and ACT scores, years of math, and masculinity scores combined account for a large amount of the variability in math self-efficacy (54%). Hackett explains that there appear to be two separate paths from gender to math self-efficacy, one she terms "direct socialization influences" through masculinity score, and the second "indirect influence of socialization" through math preparation and achievement.

Thirty-seven percent of the variance in math anxiety scores was accounted for by gender, BSRI-M, and MSES. Surprisingly, although the coefficient for the masculinity/math anxiety path was -.17, indicating that lower levels of masculinity were related to lower math anxiety, the indirect effects of masculinity on math anxiety through math self-efficacy are positive and non-significant (.02). Lastly, the science/math major choice is predicted directly by sex, years of high

school math, math self-efficacy, and math anxiety (.38).

In general, the hypothesized model was suppported by the data.

> Gender-related socialization influences in combination with amount of mathematics preparation predict level of mathematics achievement, which is, in turn, predictive of mathematics-related self-efficacy. Math self-efficacy, as influenced by these causally prior variables, is consequently predictive of both math anxiety and math-related major choice. . . .The path analysis supports the central mediational role of mathematics self-efficacy in the development of math-related careers. (Hackett, 1985, p.53)

Hackett notes that knowing the gender of a student is not enough to explain school-related mathematics behavior. She proposes that variables such as socioeconomic status, parental background, attitudes, and the influence of teachers and school systems may all contribute to the development of mathematics attitudes and behaviors.

Obviously, with only 38% of the variance accounted for by the model, there are a number of important variables missing. Hackett (1985) believes math anxiety may be operating indirectly on major choice, possible as a result of reciprocal interaction with math

self-efficacy. Hackett (1985) posits that math anxiety may in fact not be a unique contributor to math major choice, citing research by Rounds and Hendel (1980) and Dew et al. (1983) who propose that math anxiety is merely a reflection of factors such as math background and test anxiety.

Because self-efficacy suggests an ongoing, reciprocal interaction between math self-efficacy and math anxiety, achievement, vocational interests, and math-related career choice (Hackett & Betz, 1981), a static model such as that outlined above is limited in explicating this process . Hackett (1985) urges researchers to build models which account for reciprocal relationships and to develop longitudinal investigations which can trace the process of mathematics-related career choice.

A 1985 study by Siegel, Galassi, and Ware included many of the same variables investigated by Betz and Hackett. The authors attempted to compare a social learning model with a math aptitude-anxiety model in the prediction of math final exam grades. College students enrolled in an introductory math course completed a variety of measures during the last class before the exam and immediately prior to the exam.

Information on the following was collected: sex role orientation (BSRI), math anxiety (MARS), math aptitude (SAT-M). In addition, social learning variables such as previous performance (previous three exam grades), incentive to perform well on the exam (6-item Math Incentive Scale), the strength and level of math exam self-efficacy (MESES), and math exam expectancy (MEES) were assessed with measures designed by Siegel et al. (1985).

The results of the multiple regression analysis revealed that 54% of the total variance in final exam grade was accounted for by the combination of social learning variables. Previous math grades accounted for 49% of the variance, followed by math incentives (2.8%) and strength of math exam self-efficacy (1.6%). In contrast, the math aptitude-anxiety model explained 16.4% of the variance, but only SAT-M score contributed a significant amount (11.4%).

To correct for a potential confound in the way math skills were measured, Siegel et al. (1985) used SAT-M as the measure of skills in the social learning model. The results of these revised analyses show math skills, this time as measured by the SAT-M, accounting for 11.4% of the variance. Math incentives'

contribution remained nearly the same at 2.9%. However, the strength of self-efficacy became much stronger, explaining 13.3% of the variance in final exam performance. Level of self-efficacy, again, did not contribute significantly (.06%). The percentage of variance accounted for by the social learning model (28.8%) was still significantly greater than for the aptitude anxiety model (16.4%).

Clearly, self-efficacy, as measured by the MESES was not as significant a predictive variable as it is in Bandura's work with phobics. Siegel et al. (1985) suggest that discrepancies may be due to sampling and statistical differences, but also to differences in target behaviors.

Self-efficacy was measured by a Math Exam Self-Efficacy Scale specially designed for this study. Students were asked to make private judgments about their ability to correctly solve each of ten problems on the final exam after reading it for the first time. For each problem, the student indicated the degree of confidence that he or she had that they could answer the question correctly. The level of self-efficacy was calculated by tabulating the number of problems that the subject expected to solve with a confidence rating

of above one. The strength of self-efficacy was computed using the sum of the confidence ratings for each of the problems, divided by ten, the number of problems.

The above method for assessing efficacy presents some difficulty because it is not clear how well the student predicted his or her performance on specific problems. In Bandura and Adams' (1977) work with snake phobics, their microanalytic strategy correlated subjects' predictions for specific behaviors with the rating of those subsequent behaviors. Siegel et al. (1985) were, in effect, using an average or global measure of self-confidence for the entire test rather than each problem. It would have been interesting to see the relationship between students predictions for success on each problem and their subsequent performance. In addition, a one question prediction of total exam grade could have provided some valuable information.

When one asks phobics if they can or cannot hold a snake, it is relatively simple to show later success or failure. On an exam, it is likely to be more difficult for subjects to decide if they have all of the requisite knowledge needed to "succeed" on a certain

problem, especially if they are being asked to judge their ability to solve ten novel problems. Asking "can you hold a snake?" is not the same as asking "can you solve this algebraic equation?"

Incentives, the motivation to perservere on and to prepare for a task, in this case a math exam, have been linked to self-efficacy by Bandura (1982). Siegel et al. (1985) do not present a table of intercorrelations, so it is not known how much of a relationship there is between self-efficacy and math exam incentives. Certainly, preparation will affect performance, however self-efficacy for succeeding on the test would seem to play a role in motivating the student to prepare and to study.

Siegel et al.'s (1985) results lead them to recommend that treatment programs not emphasize sex role orientation or math anxiety reduction. They suggest that interventions concern themselves with math skills and building confidence and motivation, both predictive of performance.

> Performance in mathematics is highly skill dependent. If researchers and practitioners want to increase math performance among college students, they probably should first concentrate on interventions to increase these skills. In turn, these interventions might be expected to increase performances

> and efficacy expectations and, as a by-product to release anxiety toward mathematics. (Siegel et al., 1985, p. 537)

There is an ever-growing body of literature which attempts to account for American's disdain for mathematics. Studies have investigated teaching practices, physiological factors, personality characteristics, and a whole range of sociocultural factors which researchers surmise may have an influence on people's dislike and even fear of mathematics. In general, this tendency to take no more than the required math courses, to eschew math-based careers, and to publicly trumpet one's inability to balance one's checkbook or compute one's taxes, has been described as "math anxiety." As has been outlined above, although definitions of math anxiety have been proposed and measures developed to test the construct, many questions remain regarding the uniqueness of the construct and its ability to truly predict math avoidance and performance.

Recently, Bandura's self-efficacy theory, which has emerged from the larger social learning theory, has been used as a framework within which math avoidance and "anxiety" can be viewed and predicted. Largely through the combined work of Nancy Betz and Gail

Hackett, math self-efficacy has been shown to account for much of the variance in career choices of college men and women. The theory has been especially successful in explaining why women are particularly underrepresented in math courses and careers. This is important since the greater part of the "math anxiety" literature is devoted to understanding women's math achievement and participation.

However, self-efficacy can also account for young men's avoidance of math. Although there may be fewer women than men in math and science fields, the numbers of mathematicians and scientists being trained continue to decline. The American approach to teaching mathematics and to training teachers of mathematics can certainly have negatve effects on both sexes. In addition, negative images of mathematicians as cold, overly logical, socially inept, and uncreative, while closer to male stereotypes, are still not desirable images for young men to project. If young men believe that only those who possess these characteristics can succeed in math, they may well feel that they do not have a "mathematical mind" that will enable them to do well in the subject.

Siegel et al. (1985) attempted to use measures of self-efficacy to predict specific class grades. Although the measure they used accounted for only a small, yet significant amount of the variance in final exam grade, they demonstrated that social learning variables such as incentive and previous performance were much stronger predictors than a math anxiety model. Betz and Hackett (1983) and Bandura (1982) have had results which support Bandura's notion that anxiety is a "coeffect" of low self-efficacy which emerges when individuals are worried about the consequences that they believe will result from their inefficacy.

It is difficult to be successful in upper levels of mathematics if one has never mastered basic algebra or geometry, let alone arithmetic. Unfortunately, once a student has reached college-level math courses without this mastery, it is next to impossible for instructors to retrace the lessons of twelve years of math training. Colleges and universities are aware that there is a crisis in math preparation. Increasingly, interventions are being developed to try to halt and to reverse the process of math avoidance.

Interventions for Raising Mathematics Participation and Achievement

Educators have begun to take responsibility for what they see as serious problems in mathematics education. Through articles in professional journals, summer seminars, and in-class workshops, teachers and counselors are becoming sensitized to the needs of their students as well as to their own need to overcome negative, fearful expectations of mathematics. Some programs are geared toward encouraging girls in math and science, while others concentrate on developing teaching practices that will help all students.

The Talcott Mountain Science Center in Avon, Connecticut has developed a program for girls, entitled "Action Science." Girls in grades 3 through 6 attend the sessions which are taught by successful women scientists. At least one parent is required to attend the program with her or his daughter. Action Science has two major goals: 1) to expose and to train girls in the use of sophisticated scientific equipment, and 2) to teach girls to trust their own judgment and to develop independent decision-making abilities. The creator of the program felt that too often, girls deferred to the judgment of teachers and parents in

science and math classes, a sentiment echoed in a study by Frazier and Sadker (1973).

Parents were instructed not to provide too much help to their daughters, thus restricting the development of self-confidence when approaching a new task. They were asked to encourage independence, self-reliance, and decision-making abilities. Parents were made aware of how they might unintentionally discourage their daughters for fear that they would become "unfeminine" or "too assertive," traditionally inappropriate behavior for females (Reis & Rand, personal communication).

The Girls Club of America's Operation S.M.A.R.T. (Science and Math and Relevant Technology) is also geared toward increasing girls' participation in math and science. The goals of the program are to establish prgrams of informal math and science education and to develop instructional materials that will be used by schools, clubs, and other community organizations. The program will also devote energy to raising the awareness levels of schools and communities about the barriers facing girls who would be interested in math and science (AWM Newsletter, 1985).

Recently, the Children's Television Workshop, the creator of "Sesame Street," began airing "Square One," a program designed to "promote interest and enthusiasm for mathematics by developing positive attitudes toward mathematics in children from eight to twelve years of age (AWM Newsletter, 1985b, p.9). Topics covered will be arithmetic, measurement, graphs, as well as more advanced lessons in algebra, probability and statistics, geometry, topology, and infinity. The format of the show is television parody with which most child viewers should be familiar. The idea is that if mathematics is presented in an upbeat, engaging fashion, children will be attracted to the program and will receive instruction that can supplement their in-class education.

There are also programs for older students in high school. At Canton High School in upstate New York, students have finished first in both the New England and Massachusetts math tournaments for 4 years in a row, and the majority of team members are female. The Canton math department teaches its subject as a "course in the art of reasoning" (Luty, personal communication). The faculty are convinced that teaching

<u>applications</u> of mathematical principles should be priority.

Concerning the abundance of female talent, one trigonometry teacher says, "We just ignore the stereotype. We don't fall into any self-fulfilling prophecies. We don't assume females need special math treatment. We're gender-blind" (Luty, personal communication). Five of the twelve math teachers on the staff are female, providing positive role models for young women.

The Canton High math department does not want to teach math as an end in itself or just as a means to a technological career. The math teachers are dismayed at attempts to computerize the math curriculum; they would rather prepare all students, college bound or not, to use mathematics in their everyday lives. "Years from now," says one math teacher, "our students may not remember the formula for figuring out the area of a triangle, but they'll have the kind of mental discipline that makes all tasks a little more manageable" (Luty, personal communication).

One of the more well-known programs for high school girls is SummerMath at Mount Holyoke College. Jere Confrey, director of the program, saw that even

though these girls could memorize and recite formulas and theorems, they had little notion about where these formulas came from and what they meant. Like the Canton High School program, applications are emphasized, with the young women using their math skills in arts and crafts classes. They learned about radial symmetry and grid patterns through quilting and about trigonometry by building geodesic domes. For the more anxious young women, SummerMath provided a "desensitization seminar" run by a psychologist in which the girls discussed fears and and learned relaxation in the face of previously feared mathematical tasks (Salholz, 1982, p.71).

Some programs are focusing on changing teachers' attitudes and their strategies for teaching math. The EQUALS program at the University of California at Berkeley was organized to train teachers and administrators in methods designed to improve girls' achievement in math. The basic principles include 1) making math interesting and attractive, 2) making girls aware of how useful math will be in their lives, 3) teaching math skills that use logic and reasoning. Some of the techniques include a "math menu" of five weekly activities labelled from "appetizer" to

"dessert," and a show and tell of local career women who use math (Prola, 1984).

Larson (1983) has developed some techniques for changing negative attitudes in elementary education majors. She advocates raising the topic of "math anxiety" during the first session of math classes designed for teachers and encourages teachers-in-training to share their personal math histories. All during that initial session, students should be asked to monitor their feelings as they engage in mathematics.

Larson suggests that preservice teachers enrolled in math courses should be organized into small groups for problem solving exercises since it is easier for students to take risks in a small group setting. Students will also be supportive of each others' math development, in contrast to a large lecture where students set out on their own to find the "one right answer." Working in groups of three or four also reduces the anxiety that comes with being totally responsible for an answer. Larson's other methods to build confidence in preservice elementary teachers include trying a variety of approaches to solving one

problem and using concrete materials to learn mathematical approaches.

Finally, elementary and secondary teachers can learn methods for analyzing students' problems in mathematics and learn new instructional techniques at Mt. Holyoke's SummerMath for Teachers. One of the themes of the institute is "Young Women and Mathematics." Teachers learn how they might avoid communicating attitudes that would make young women reluctant to pursue math courses and careers and discuss the problems that women face in entering math-related careers.

Dueball and Clowes (1981) of Virginia Polytechnic University surveyed Virginia's state and private higher education institutions to see how prevalent programs to alleviate math anxiety and avoidance were. Twenty-one percent of the public colleges and 13% of the private colleges were offering some type of math anxiety program. The majority of these schools had enrollments of over 8000 students.

Dueball and Clowes (1981) organized the programs along a continuum ranging from a math-dominated approach to a counseling-dominated approach. The latter often incorporated one or more of the following:

1) anxiety management training, 2) desensitization, 3) accelerated massed desensitization, or 4) a support group. Anxiety management training uses deep muscle relaxation in conjunction with concentration on an anxiety-arousing situation, desensitization employs a hierarchy of anxiety-provoking experiences, accelerated massed desensitization exposes the student to only the highest levels of the desensitization hierarchy, and the support group generally involves students sharing their math-related experiences. The math-dominated approach may consist of a math course, math lab, or both, with the idea that developing competence will reduce anxiety. Programs were administered through counseling centers, psychology departments, continuing education centers, women's centers, and math departments.

These programs are all important efforts for improving the attitudes and skills of students and teachers. They incorporate anxiety management, cognitive restructuring, and consciousness raising techniques that the literature has suggested may be useful. However, none of the studies listed above has resulted in an empirical test of these methods. If gains are to be made in the area of math avoidance, it

is important to know which techniques are contributing to the positive outcome. Although programs geared toward teachers and young children are essential if we are to eliminate math avoidance, in the interim we need to develop interventions that will help college-aged students who are presently enrolled in math courses.

Suinn, Edie, and Spinelli (1970) were among the first to validate empirically their method for using accelerated desensitization to reduce math anxiety. Subjects volunteered for a behavior therapy program to treat math anxiety. Criteria for participation included absence of a psychosis, presence of anxiety related to a wide variety of number-associated situations, evidence of adequate study skills, and general intellectual ability. Suinn et al. (1970) expressed the wish to "avoid treatment of subjects whose poor performances with numbers was really due to lack of ability or preparation rather than the interference of anxiety" (p. 306).

Students took the Math Anxiety Rating Scale (MARS) and the math section of the Differential Aptitude Test (DAT). All subjects were given one hour of relaxation training and then two treatment groups were formed. A marathon desensitization group was exposed to five

treatment blocks within 4 hours of one evening and an accelerated massed desensitization group was given only the highest items of a desensitization hierarchy. Both groups produced significant improvement in math anxiety and on the DAT to an equivalent degree. The authors claim that interview data support their contention that mathematically-related behavior improved as well.

Several years later, Richardson and Suinn (1973) extended this research, comparing traditional systematic desensitization, accelerated massed desensitization, and anxiety management training in the treatment of math anxiety. The same criteria and measures of treatment were used as in Suinn et al. (1970). Suinn and Richardson (1971) describe anxiety management training as the "elicitation of arbitrary anxiety responses and the training of competing responses" (p. 213). In this study, two no-treatment controls were also compared.

Contrary to Richardson and Suinn's (1973) predictions, there was no significant difference between the traditional systematic desensitization, accelerated massed desensitization, and a non-treatment control on the DAT. Richardson and Suinn (1973)

postulate that earlier differences may have been due to practice effects. There were, however, significant reductions in anxiety as measured by the MARS for all the experimental groups. Richardson and Suinn explain the reduction in MARS scores as stemming from the strengthening of the conditioning between relaxation and math situations over the connection of math and anxiety. They infer that anxiety can still be present after counterconditioning as long as it is a weaker response than relaxation.

Richardson and Suinn's (1973) choice of a behavioral outcome measure is curious. The DAT contains litle math that college-aged students would be studying. If the subjects were chosen because they feared a wide variety of mathematical situations rather than just test situations, why give them a math test to show their improvement? While it is true that experimental subjects alone reduced their MARS scores, paper and pencil measures about how uncomfortable subjects feel are not the same as measuring their behavior in a math situation.

Furthermore, Richardson and Suinn (1973) and Suinn et al. (1970) had carefully screened their subjects so that they had adequate math preparation and study

skills. In most cases, as this review has shown, anxiety about math is intertwined with lack of preparation and inadequate capabilites for studying the subject. Programs to alleviate the fear and avoidance of math courses and tasks cannot have the luxury of taking only those students who have had excellent math training. The authors concentrate on the alleviation of math anxiety as was popular in the 1970's and still is to some degree. But as the studies by Suinn et al. (1970) and Richardson and Suinn (1973) have shown, by reducing anxiety, one cannot necessarily improve performance.

Hendel and Davis (1978) tried a somewhat different approach to treating what they, too, called math anxiety. Their intervention was geared to a "symptom" of math anxiety, "math avoidance." The goal of the treatment was to develop constructive client self-talk.

Subjects were sixty-nine females ranging in age from 19 to 59 years of age. Almost all subjects had at least some college or had completed a four year degree but had been away from formal math instruction for an average of 18 years. All women attended a diagnostic clinic designed to assess their math skills and to examine how their math anxiety might be contributing to

their poor performance. Afterward, the women had three options: 1) to discontinue the program, 2) to enroll in one of three math classes, or 3) to enroll in a class concurrently with a seven week support group.

Although those who participated in the diagnostic clinic did not differ initially on the MARS, all of those who completed either a course or the support group reduced their MARS scores significantly, and those who had taken both the course and the support group showed the greatest decrease. Again, problems arise with the use of the MARS as an outcome measure. It would have been interesting to see the differences in some kind of behavioral measure such as course grade. Also, the female participants were recruited from a continuing education center and were probably highly motivated to alter their fear of math. Hendel and Davis (1978) neglected to include an equally anxious control group.

Judy Genshaft (1982) also examined the effects of an intervention strategy on women. She recognized the self-perpetuating cycle of avoidance, poor performance, and anxiety that many women experience. Her strategy was to break the cycle of negative <u>cognitions</u> that maintain anxiety and avoidance. She employed

Meichenbaum's self-instruction training which is designed to "influence the nature of the individual's internal dialogue so as to increase self governance and self control" (Genshaft, 1982, p. 33).

The young women in the study were seventh graders who had demonstrated math achievement one year below their reading achievement and whose teachers had identified them as being anxious. They were assigned to one of 3 groups. The control group attended math class but received no remediation. The tutoring group met twice weekly for 8 weeks and received 40 minutes of tutoring in math in addition to their regular classroom instruction. Young women assigned to the self-instruction group attended class, tutoring sessions, and used self-instruction techniques to "reduce their anxiety and to help them attend more appropriately to the task, and not to make critical self-evaluative ruminations" (Genshaft, 1982, p. 33).

The effectiveness of these strategies was evaluated using the computation and applications sections of the Stanford Diagnostic Mathematics Test and an unnamed attitudes questionnaire. The self-instructon group was the only one to improve significantly on the computations section, but all 3

groups improved on the applications section. Genshaft (1982) also reports significant improvement in attitudes toward math for only the self-instruction group, although she does not present any statistics which elucidate this improvement.

The focus of these studies has been the reduction of anxiety. The assumption has been that if physical symptoms have been eliminated, students will suddenly be able to learn math. Hendel and Davis (1978) and Genshaft (1982) make reference to the impact of negative attitudes toward women's participation, yet it is not clear how they theoretically integrate attitudes and anxiety. Genshaft (1982) uses cognitive theory as a backdrop for her study, yet her main focus is on using cognitions to reduce anxiety rather than to build positive self-efficacy in regard to mathematics.

Probert's (1983) approach is more in line with Bandura's idea that anxiety is merely a coeffect of low self-efficacy. Although her program for building "math confidence" is informed largely by the literature on math anxiety, it concentrates more on building positive beliefs about one's ability to succeed in math than on reducing physiological anxiety associated with performing mathematical tasks. Probert (1983) conducted

a series of math confidence groups for students currently enrolled in either undergraduate or graduate classes. Students responded to posters advertising the groups or were referred by counselors at the university counseling center. An initial interview screened students for serious psychological disturbance and basic intellectual aptitude. Students were required to have achieved at least a 2.0 grade point average.

The intervention was multimodal in nature, using Ellis' Rational Emotive Therapy to modify students' negative self-statements, relaxation training to alleviate anxiety, and self-monitoring and traditional study techniques to improve study skills. The groups spent approximately one hour in each of the 7 weekly sessions in an open support group format. Homework assignments were given weekly to help students to become aware of their attitudes about math and to reinforce group lessons. One session was devoted to using alternative strategies to solve word problems, however the groups were based more on a counseling approach than on a mathematical instruction format.

Probert (1983) conducted 6 groups, yet upon examination these groups were sufficiently different in background and level of anxiety that it was impossible

to combine them for statistical analyses. Probert examined before and after treatment differences in math attitudes, anxiety, and in self-estimates of math ability and found significant improvements on all variables for 5 of the 6 groups relative to a control group.

Probert's approach was essentially a cognitive behavioral one. Although she does not state explicitly that her treatment approach is based on Bandura's four modes of influence, her intent was to change students' negative cognitions about themselves as learners of mathematics through a muti-modal approach, and thus, to build positive math self-efficacy. Probert's (1983) students changed their attitudes toward math and reduced their math anxiety, however measures designed to assess self-efficacy specifically were not available at the time of her study. One of the goals of the present study was to replicate Probert's (1983) successful intervention, using her basic group format and materials, while attempting to describe how the confidence groups work specifically by building self-efficacy.

Hypotheses

The present study sought to carry out the recommendations of Betz and Hackett, who in their recent studies have shown Bandura's self-efficacy theory to be useful in explaining math avoidance and the anxiety that sometimes accompanies it. Using Probert's (1983) group format, math confidence groups were studied to investigate whether or not they can produce gains in math self-efficacy, reduce math anxiety, and improve math course grades. The groups used techniques designed to draw upon Bandura's modes of influence, performance attainments, vicarious learning, verbal persuasion, and physiological states.

One of the themes of the math confidence counseling groups was the focus on stereotypes of mathematicians and their effect on both males and females conceptions of themselves as learners and doers of mathematics. Becoming good at math has many implications for one's entire self-concept. Those who do not want to be labelled with all of the negative characteristics often associated with mathematics are in a bind. They may feel inefficacious in regard to mathematics because they do not fit the stereotype, yet they may not want to become good at math because they

feel they would <u>have</u> to take on some of these very same unattractive traits. One of the aims of the math confidence groups was to raise students' math self-efficacy by disputing these stereotypes of mathematicians as socially inadequate, boring, and overly logical. The idea was to have achievement in math carry fewer implications for the students' overall self-concepts.

Math instruction groups have been another popular way of combatting math avoidance and fear (Dueball & Clowes, 1981; Genshaft, 1982). The counseling approach of the math confidence groups was compared with tutoring groups to test which was more effective in raising self-efficacy. In addition, a no treatment control was used as a comparison group.

A more pragmatic consideration of this study concerns its use as a tool in the development of a permanent psychology department service to students enrolled in a mandatory statistics course sequence. The department in question has long noted a high dropout and failure rate from the required statistics courses and sought a remedy for this problem. Therefore, all subjects were currently enrolled in Statistics I or II and a behavioral measure of the effectiveness of the

groups, final course grade, was available. Students were not screened for GPA or for math preparation as in the Probert (1983), Richardson and Suinn (1973), and Suinn et al. (1970) studies because the aim was to have the intervention accommodate all students in the department.

The following hypotheses were advanced:

1. Math confidence groups will make signficantly greater gains in math self-efficacy than either the tutoring groups or the control groups.

2. Math confidence groups will reduce their math anxiety to a significantly greater degree than either the tutoring or control groups.

3. Math confidence groups will raise their self-estimate of math ability to a significantly greater extent than either the tutoring or control groups.

4. Math confidence groups will achieve significantly higher grades than either the tutoring or control groups.

5. Math confidence groups will make significantly greater reductions in the number of implications mathematics holds for other areas of the students' self-concept than either the tutoring or control groups.

CHAPTER THREE
METHODS

Subjects

The initial sample was drawn from students who had been accepted as psychology majors during the Fall 1985 semester. During the second week of the Spring 1986 semester, these students received a mailing welcoming them to the psychology department (Appendix 1) and requesting that they complete the following measures: the Mathematics Self-Efficacy Scale (Betz & Hackett, 1983; Appendix 2), the Math Anxiety Scale (Fennema & Sherman, revised by Betz, 1978; Appendix 3), and the Bem Sex-Role Inventory (Bem, 1974; Appendix 4). Students were also asked to respond to a background information questionnaire on which they indicated their degree of high school and college math preparation, whether or not they were presently enrolled in STA 3023 or STA 3024, their self-estimate of their mathematical/statistical ability, and their willingness to participate in a statistics confidence program (Appendix 5). Students were asked to return the completed form to the Department of Psychology.

During the third week of the semester, after the initial mailing had been distributed, I made an

additional announcement about the progr am in each of the undergraduate statistics classes. At that time the pretest measures were distributed to all psychology majors without regard to when they were accepted into the major. Students in the sections of STA 3023 were asked to return their questionnaires to the instructor or to the Department of Psychology, whereas students in STA 3024 completed the questionnaires during class time.

One hundred and sixty-nine students completed questionnaires. Ninety-six indicated an interest in participating in a statistics confidence building program. Initially, interested students were randomly assigned to either a math confidence group, a statistics tutoring group, or a no treatment control using a random number table, but due to scheduling considerations, four students who were originally assigned to one experimental group were reassigned to another.

Students who indicated interest, but whose self-estimates of math ability were "very good" or "excellent" were eliminated from consideration. Ten percent of students interested in the statistics confidence program indicated their math/statistics

ability was either "very good" or "excellent" as compared with 32% of students who did _not_ indicate an interest in the program. Students were contacted by phone to arrange their placement in one of the 7 scheduled groups (4 statistics confidence, 3 tutoring.) There were originally 31 students assigned to one of the 4 statistics confidence groups, 25 students assigned to one of the 3 tutoring groups, and 23 assigned to the no treatment control. Unfortunately, some students never attended their groups while others attended only a few sessions. An additional problem was obtaining post-test data from control subjects and subjects who did not attend the last session of either the tutoring or math confidence group. Table 1 shows the number of sessions attended by those who completed both pre- and posttest questionnaires.

Table 1: Mean Number of Sessions Attended by Students for Whom Pre- and Posttest Data was Available.

Confidence Groups				Tutoring Group		
1	2	3	4	1	2	3
5.5 (n=2)	6.0 (n=3)	4.75 (n=4)	5.0 (n=4)	2.33 (n=3)	2.0 (n=5)	4.5 (n=2)

T-tests were conducted on the pretest measures of those for whom posttest measures were available versus those for whom they were not available. Although there were no significant differences on any of the dependent variables for the confidence groups, the non-persisting tutoring group scored significantly lower on measures of self-estimate of math ability and math anxiety. Results of the t-tests and the means and standard deviations are shown in Table 2 and Table 3.

Instrumentation

Mathematics Self-efficacy Scale

The Math Self-Efficacy Scale (MSES, Betz & Hackett, 1983) was developed in order to assess students' self-efficacy expectations along three dimensions:1) academic math problems, 2) every day math problems, e.g. tabulating a dinner bill, and 3) college math courses. The scale consists of 52 questions, 18 math tasks, 16 math-related college courses, and 18 math problems. Subjects are asked to indicate the level of confidence they have in their ability to successfully perform a task, solve a problem, or pass a math course with a grade of B or better using a 10 point Likert-type scale (0=no confidence to 9=complete confidence). Scores are tabulated for each subscale as well as for the entire

Table 2

Means, Standard Deviations, and T-test Comparison of Persistors versus Non-persistors in Confidence Groups on MSES, SE, MAS, and GPA.

Variable:Math self-efficacy					
	$\overline{X}$	SD	T	DF	P
Persistors	307.72 n=12	36.61	.21	19	ns
Non-Persistors	311.55 n=11	43.15			

Variable:Self-estimate of math ability					
	$\overline{X}$	SD	T	DF	P
Persistors	3.76 n=13	1.09	.68	22	ns
Non-Persistors	3.45 n=11	1.13			

Variable:Math anxiety					
	$\overline{X}$	SD	T	DF	P
Persistors	22.00 n=12	8.0	.44	21	ns
Non-Persistors	20.54 n=11	6.8			

Variable:GPA					
	$\overline{X}$	SD	T	DF	P
Persistors	2.77 n=10	.76	.16	18	ns
Non-Persistors	2.82 n=10	.64			

Table 3

Means, Standard Deviations, and T-test Comparison of Persistors versus Non-persistors in Tutoring Groups on MSES, SE, MAS, and GPA.

Variable:Math self-efficacy

	$\bar{X}$	SD	T	DF	P
Persistors	303.9 n=10	50.34	.28	14	.ns
Non-Persistors	295.83 n=6	51.00			

Variable:Self-estimate of math ability

	$\bar{X}$	SD	T	DF	P
Persistors	4.2 n=10	.78	2.36	14	.05
Non-Persistors	3.16 n=6	.98			

Variable:Math anxiety

	$\bar{X}$	SD	T	DF	P
Persistors	25.7 n=10	6.65	2.38	14	.05
Non-Persistors	18.0 n=6	5.47			

Variable:GPA

	$\bar{X}$	SD	T	DF	P
Attenders	2.99 n=9	.47	1.69	9	ns
Non-Attenders	2.55 n=3	.25			

fifty-two item scale. Higher scores indicate greater mathematical self-efficacy.

The MSES has been demonstrated to be internally consistent with alpha = .90 for the math tasks, .93 for the math courses, .92 for the math problems, and an overall reliability of .96 for the entire scale (Betz & Hackett, 1983). Betz and Hackett (1983) also demonstrated a correlation of .66 between the MSES and a measure of math confidence (Math Anxiety Scale, Fennema & Sherman, revised by Betz, 1978).

Attitudes Toward Mathematics: Math Anxiety Scale

The Math Anxiety Scale (MAS) is one of 5, 10-item scales which form the Attitudes Toward Mathematics Scale (Fennema & Sherman, revised by Betz, 1978). Using a 5-point Likert-type scale (1 = strongly disagree to 5 = strongly agree), students indicate the level of anxiety and discomfort they experience when performing various math tasks. Negatively worded items (6-10) are reversed scored. Lower scores indicate greater math anxiety.

Betz (1978) reports a split-half reliability coefficient of .92 for the Math Anxiety Scale. Dew et al. (1983) reported that Cronbach's alpha was.74 and that the 2 week test-retest correlation was .86 for

women and .88 for men. Dew et al. (1983) considered the Math Anxiety Scale to have both acceptable internal consistency and test-retest reliability. Frary and Ling (1983) conducted a factor analytic study of various scales that were purported to measure attitudes toward mathematics and found the Math Anxiety Scale to have a very high loading (.89) on the factor they called mathematics anxiety. Probert (1983) found a relationship between the MAS and math background ($\underline{r}$ = .30), quantitative SAT ($\underline{r}$ = .40), and a measure of confidence in learning mathematics ($\underline{r}$ = .84).

Bem Sex-Role Inventory

To investigate the role of gender identity in math self-efficacy, the Bem Sex-Role Inventory (BSRI, Bem, 1974) will be used. The BSRI consists of 60 personality characteristics, twenty designated as traditionally feminine, 20 as traditionally masculine, and 20 considered neutral. Respondents use a 7-point Likert-type scale (1 = never or almost never true to 7 = always or almost always true) to describe how closely they feel they resemble each of the 60 characteristics. For each subject, the mean self-ratings for the endorsed masculine and feminine items are determined to give the person a Masculinity and Femininity score.

Both the Masculinity and Femininity scales of the BSRI have been found to be internally consistent (alpha = .86 and .80, repectively) and to be reliable over a period of one month (Masculinity = .90, Femininity = .90; Bem, 1974).

Implications Grid

Of related interest is the importance for subjects of constructs related to their mathematical/statistical ability and confidence. In order to assess how other personality characteristics might influence and be influenced by mathematical/statistical self-efficacy expectations, a 10 X 10 implications grid will be used (Hinkle, 1965, cited in Fransella & Bannister, 1977, Appendix 6). The grid methodology is commonly associated with George Kelly's Personal Construct Theory. Kelly (1955) posited that after repeatedly interacting with the environment, individuals develop bipolar dimensions along which they organize their experiences. These dimensions, or "constructs," are organized into hierarchical "construct systems" with "superordinate" constructs having the greatest number of relationships with subordinate constructs throughout the system.

Hinkle's (1965) implication grid enables one to determine which constructs are superordinate, that is, which constructs, if altered would have the greatest implications for change along all the other construct dimensions. For example, a woman might associate the concept of "math confidence" with "masculinity," "social discomfort," and "unattractiveness." Math confidence vs. math anxiety could be considered a superordinate construct because it had many relationships with other constructs. If she were asked to suddenly think of herself as "math confident" when she formerly considered herself to be "math anxious," she would also have to rethink her conception of herself as feminine, socially at ease, and attractive; therefore the construct "math confident vs. math anxious" has many <u>implications</u> for other constructs.

Subjects were given a 10 X 10 grid and were asked to list 7 things they liked about themselves on the left side of the grid and the polar opposites of these qualities on the right side of the grid. In addition to the elicited constructs, the following constructs were on each grid: 1) math anxious vs. math confident, 2) mathematician vs. non-mathematician, and 3) feminine

vs. masculine. The subject was then given the following instructions:

> Consider this construct for a moment (Construct 1). Now, if. . .you woke up one morning and realized that you were best described by one side of this construct while the day before you had been best described by the opposite side- what other constructs of these (nine) remaining ones would be likely to be changed by a change in yourself on this one construct alone? (Hinkle, 1965, cited in Fransella & Bannister, 1977, p. 43)

The grid is scored by adding up the total number of implications carried by each construct and rank ordering them.

Procedure

Subjects assigned to one of the 4 statistics confidence groups attended for one and one half hours per week for 5 weeks. The groups were led by advanced graduate students in counseling psychology who were supervised by a licensed psychologist. During the first session, subjects completed the math implications grid before the beginning of the group. Groups followed the basic procedures outlined in Probert's (1983) dissertation entitled, "Math Confidence Workshops: A Multimodal Group Intervention Strategy in Mathematics Anxiety/Avoidance."

Following Probert (1983), subjects were introduced to the group with the following rationale: 1) They have the ability to succeed in statistics and other math classes, 2) negative statements they make to themselves have the power to affect their performance, 3) myths and stereotypes about the types of people that can do math contribute to the creation of negative self-statements. The goals of the group included: 1) replacing negative cognitions about one's ability to succeed in statistics, 2) disputing stereotypes of mathematicians and myths about how math is done, 3) teaching study skills and problem solving techniques, and 4) reducing anxiety and building self-efficacy through relaxation training and positive visualization. Outlines of each of the six sessions are provided in Appendix 7.

As outlined in Probert (1983), each group began with "rounds" where each person shared their experiences with statistics through the use of weekly journals and study graphs. The "rounds" constituted part of the verbal persuasion and vicarious learning portions in each group. Anxiety management and self-monitoring exercises drew upon Bandura's fourth mode of influence, physiological states. Finally,

students' use of techniques learned in the group in their classes, along with in-group solving of word problems gave them information about performance attainments. During the final group session, members completed the posttest, consisting of the MSES, the self-estimate of ability (SE) the MAS, the BSRI, and the Impgrid.

Students assigned to statistics tutoring groups met for 6, one and a half hour sessions led by graduate students in statistics. There was no designated format. Students brought in homework problems or discussed material covered in class. Tutors were not instructed to consciously employ any of Bandura's modes of influence, although they were no doubt present to some extent. The rationale for including this type of group was that students who are having difficulty are commonly referred to tutors by their teachers and by their college's advising department. Students who were assigned to the no treatment control were told that due to the experimental nature of the program, there were only a few openings available in the program and they were currently filled.

CHAPTER FOUR
RESULTS

Major Hypotheses:Math Self-Efficacy, Math Anxiety, Self-Estimate of Math Ability

The hypotheses regarding the performance of the math confidence, tutoring, and no-treatment control groups were tested via 3 X 2 repeated measures analyses of variance. None of the three groups differed significantly on the pretest for any of the dependent variables (Table 4). The hypotheses predicting that participants in the confidence group would score significantly higher on the Math Self-Efficacy Scale (MSES) and the Math Anxiety Scale (MAS) than the other two groups were not supported. There were no significant interactions between group and time for the total or any of the subscales of the MSES or for the MAS. There was a significant time effect, however, for the MAS ($\underline{F}$ = 14.16, $\underline{p}$ < .001; ANOVAs shown in Table 5). The means in Table 6 show that both the math confidence and tutoring groups were less anxious at posttesting (higher scores indicate lower anxiety).

The hypothesized interaction between time and group for self-estimate of math ability (SE) was borne out by the data. There was a significant effect for

time (*F* = 6.20, *p* < . 02) and a significant group by time interaction (*F* = 3.71, *p* < .04, Table 5). An *F*-test for simple effects was carried out to determine which groups were involved in the interaction (Table 7). The math confidence groups raised their self-estimates significantly higher than the tutoring groups (*F* = 6.52, *p* <.025) and the control group (*F* = 4.35, *p* < .05). The tutoring groups' scores did not differ significantly from the control group's.

Table 4

Results of Pretest ANOVA's Among Confidence, Tutoring, and Control Groups for SE, MSES, and MAS.

Variable:SE

Source	DF	SS	MS	F	P
Group	2	1.05	.53	.58	.57
Error	26	23.91	.92		

Variable:MSES

Source	DF	SS	MS	F	P
Group	2	21524.40	10762.2	2.16	.13
Error	26	129695.73	4988.3		

Variable:MAS

Source	DF	SS	MS	F	P
Group	2	81.30	40.65	.82	.54
Error	26	1296.01	49.84		

Table 5

Repeated Measures ANOVA's for SE, MSES, and MAS

Variable:SE

Source	DF	SS	MS	F	p
Time	1	2.89	2.89	6.20	.02
Time X Group	2	3.45	1.72	3.71	.04
Error	26	12.13	.46		

Variable:MSES

Source	DF	SS	MS	F	p
Time	1	6178.43	6178.43	2.21	.14
Time X Group	2	11846.42	5923.21	2.12	.14
Error	26	72754.85	2798.26		

Variable:MAS

Source	DF	SS	MS	F	p
Time	1	413	413	14.16	.001
Time X Group	2	190	95	3.26	.10
Error	25	729	29.16		

Table 6

Means and Standard Deviations of Pre-and Posttest Data for Math Confidence, Tutoring, and Control Groups for SE, MSES, and MAS

	Math Confidence		Tutoring		Control	
TIME	1	2	1	2	1	2
SE	3.76 (1.09) n=13	4.84 (.69) n=13	4.20 (.78) n=10	4.20 (1.03) n=10	4.00 (.89) n=6	4.3 (1.36) n=6
MSES	324 (68.28) n=13	355 (40.59) n=13	304 (49.67) n=10	326 (40.48) n=10	367 (100.92) n=6	352 (48.32) n=6
MAS	22.38 (7.78) n=12	31 (4.9) n=12	25.70 (6.65) n=10	30.5 (6.91) n=10	25.83 (5.84) n=6	25.16 (7.25) n=6

Table 7

F-test Analysis of the Group X Time Interaction Between Math Confidence and Tutoring Groups, Math Confidence and Control Groups, and Tutoring and Control Groups for SE

Comparison:Math confidence vs.Tutoring

Source	DF	SS	MS	F	p
Time X Group	1	2	2	6.52	.025
Error	26	12.12	.46		

Comparison:Math confidence vs. control

Source	DF	SS	MS	F	p
Time X Group	1	2	2	4.35	.05
Error	26	12.12	.46		

Comparison:Tutoring vs. control

Source	DF	SS	MS	F	p
Time X Group	1	0	0	0	-
Error	26	12.12	.46		

Implications Grid

It was predicted that the number of implications that mathematics held for subjects' self-concepts would decrease to a significantly greater extent for participants in the math confidence groups relative to the tutoring and control groups. Unfortunately, it was impossible to obtain posttest data from the control group, so analyses were only carried out between the confidence and tutoring groups.

A repeated measures analysis of variance indicated that there was no significant change over time in the number of implications for the two groups, but that the interaction between group and time approached significance ($F = 3.77$, $p < .06$; Table 8). The analysis was carried out on only 17 grids, due to missing data for 6 subjects. Means and standard deviations are presented in Table 9.

To support the inferences that it was the disputation of negative stereotypes that caused changes in the number of implications that math held for students' self-concepts, an analysis of confidence groups' homework assignments for the first and fifth sessions was performed using Murphy and Neimeyer's Auto-Rep software package. Students were asked to

complete a short paragraph describing the "typical mathematician" after the first and fifth confidence groups. The Auto-Rep program categorizes the adjectives subjects used in their paragraphs and converts them into percentages of total adjectives or constructs used. As can be seen in Table 10, students in the confidence groups altered their negative stereotypes in the expected direction for many of the personality categories.

Grades

In order to test the "real-life" significance of the confidence and tutoring groups, the final grade in the statistics course was examined. It was hypothesized that the math confidence groups would have the highest grades. The one-way ANOVA failed to support this hypothesis ($\underline{F}$ = .35 , $p > .71$; Table 11). Means and standard deviations for the three groups are shown in Table 12).

Correlational Analyses

Correlations were computed among the following variables using Pearson product-moment correlations: MSES, Course (CRS), Problems (PRB), and Task (TSK) subscales of the MSES, SE, MAS, BSRI-M, BSRI-F, GPA,

Table 8

Repeated Measures ANOVA for Impgrid for Math Confidence and Tutoring Groups

Variable:Impgrid

Source	DF	SS	MS	F	p
Time	1	36.30	36.30	.58	.45
Time X Group	1	235.20	235.20	3.77	.06
Error	18	1123.80	62.43		

Table 9

Means and Standard Deviations of Pre- and Posttest Impgrids for Math Confidence and Tutoring Groups

	Math Confidence		Tutoring	
Time	1	2	1	2
	26 (10.6) n=12	22.2 (11.48) n=12	17 (8.50) n=5	21 (8.10) n=5

Table 10

Content Analysis of Confidence Group Homework Assignment: "Describe a Typical Mathematician"

	Pretest $\bar{X}$%	Posttest $\bar{X}$%
1. Social Interaction		
High	20.9	43.5
Low	7.5	5.5
2. Forcefulness		
High	17.8	5.6
Low	3.8	1.9
3. Organization		
High	14.4	5.5
Low	-	-
4. Self-sufficiency		
High	2.2	-
Low	-	-
5. Status		
High	3.8	1.9
Low	-	-
6. Factual Description	16.5	12.0
7. Intellective		
High	11.1	7.5
8. Self-Reference	-	6.5
9. Alternatives		
Open	3.8	-
Closed	2.2	5.5
10. External Appearance	17.2	12.0
11. Emotional Arousal	5.9	-
12. Egoism	-	1.9
13. Tenderness		
High	9.3	8.3
Low	5.9	-
14. Time Orientation		
Past	-	-
Future	1.9	-
15. Involvement		
High	-	3.7
Low	3.7	-

Table 11

One-way ANOVA for Grade for Math Confidence, Tutoring, and Control Groups

Variable:Final Statistics Grade

Source	DF	SS	MS	F	p
Group	2	153.05	76.52	.35	.71
Error	26	5746.63	221.02		

Table 12

Means and Standard Deviations for Final Course Grade for Math Confidence, Tutoring, and Control Groups

Math Confidence	Tutoring	Control
2.75 (1.23) n=9	2.72 (.83) n=9	3.10 (1.24) n=6

A = 4.0	C+ = 2.5	D = 1.0
B+ = 3.5	C = 2.0	E = 0
B = 3.0	D+ = 1.5	

and Grade (Table 12). MSES and MAS were significantly correlated on the pretest (*r* = .45). As total math self-efficacy rises, math anxiety decreases. Posttest MSES (MSES2) and SE were significantly related on the postest (*r* = .57), though not on the pretest. However the pretest SE was correlated with the MSES posttest as well (*r* = .50). The coursework and task subscales appear to account for a good deal of this correlation between MSES2 and SE2. The correlation between CRS2 and SE2 is *r* = .67, and between TSK2 and SE2 is *r* = .41. Grade point average showed a significant relationship to SE, both on the pretest (*r* = .36) and on the posttest (*r* = .45), and to the TSK subscale on the posttest (*r* = .47).

Post-hoc Analyses

In order to obtain subjects for the experimental procedure, psychology majors in all of the Spring 1986 Statistics classes were given the MSES, MAS, SE, and BSRI. There were 169 students who completed at least one part of the pretest. Correlations were computed among the pretest measures, final grade, and GPA and those that were significant are shown in Table 13.

MSES and each of its subscales were all moderately correlated with MAS (MSES:*r* = .49; CRS:*r* = .47; PRB: *r*

= .44; TSK:r = .45; the greater the math self-efficacy, the lower the math anxiety. MSES and the coursework and task subscales had low to moderate relationships to BSRI-M (r = .19; r = .21; r = .24, respectively). Higher masculinity scores seem to facilitate self-efficacy expectations regarding math coursework and mathematical tasks, though not problem solving. MSES and all of its subscales were moderately correlated with SE (MSES: r = .65; CRS: r = .65, PRB: r = .58; TSK r = .45). With an r = .65 between MSES and SE, one can infer that one question which asks one to estimate his or her math ability shares a great deal with the much longer MSES. MAS is also positively related to SE (r = .65), with higher SE related to lower math anxiety scores.

Grade point averages and final grades were available from fewer of the subjects. MSES appears to bear some relationship to GPA (r = .29), most notably the coursework subscale (r = .49). Likewise, SE is also moderately related to GPA (r = .34). Not surprisingly, GPA and final statistics grade were significantly related (r = .51).

The correlations computed among final math grade and the other dependent variables show low to moderate

relationships between grade and MSES and also for the coursework and problems subscales (*r* = .28; *r* = .42; *r* = .20, respectively). Final grade also appears to be affected by MAS to some degree (*r* = .29). The higher the grade, the more likely that math confidence was higher. Finally, final grade was positively related to SE (*r* = .36). These students seem to do only moderately well at predicting their own performance.

A stepwise multiple regression analyses was conducted with final course grade as the dependent variable (Table 14). The independent variables included SE, MSES, MAS, BSRI-F, BSRI-M, GPA, and sex. Only GPA and MAS contributed a significant amount of the variance (R2 = .17; R2 = .10, respectively).

Table 13

Matrix of Pearson Product-Moment Correlations Among Dependent and Independent Variables for Experimental Subjects.
(n=29)

	MSES1	MSES2	CRS1	CRS2	PRB1	PRB2	TSK1	TSK2
MSES1		.19 ns	-.12 ns	.10 ns	.35 ns	.28 ns	.25 ns	.10 ns
MSES2			.31 ns	.91 ****	.14 ns	.75 ****	.18 ns	.73 ****
CRS1				.26 ns	.66 ****	.28 ns	.65 ****	.21 ns
CRS2					.03 ns	.49 **	.10 ns	.58 ***
PRB1						.26 ns	.90 ****	.11 ns
PRB2							.19 ns	.40 *
TSK1								.20 ns

$*$ $p < .05$ $***$ $p < .001$
$**$ $p < .01$ $****$ $p < .001$

Table 13

	MAS1	MAS2	BSRI-M1	BSRI-M2	GPA	GRD	SE1	SE2
MSES1	.45 **	-.14 ns	.24 ns	.30 ns	.12 ns	-.04 ns	.32 ns	.01 ns
MSES2	.16 ns	.18 ns	.08 ns	.26 ns	.23 ns	.31 ns	.50 **	.57 ***
CRS1	.20 ns	.17 ns	.08 ns	.32 ns	-.06 ns	.29 ns	.07 ns	.12 ns
CRS2	.20 ns	.17 ns	.08 ns	.32 ns	.31 ns	.32 ns	.52 **	.67 ****
PRB1	.20 ns	.57 ****	-.03 ns	.03 ns	-.11 ns	.03 ns	-.03 ns	.13 ns
PRB2	.11 ns	.17 ns	.06 ns	.11 ns	.07 ns	.03 ns	.26 ns	.19 ns
TSK1	.20 ns	.07 ns	-.56 ***	-.07 ns	-.06 ns	-.25 ns	.03 ns	-.15 ns
TSK2	.01 ns	.06 ns	.03 ns	.13 ns	.08 ns	.47 **	.41 *	.41 *

* $p < .05$ *** $p < .001$
** $p < .01$ **** $p < .001$

Table 13

	MAS2	BSRI-M1	BSRI-M2	GPA	GRD	SE1	SE2
MAS1	.16 ns	.24 ns	.28 ns	.04 ns	.19 ns	.51 **	.27 ns
MAS2		.00 ns	.02 ns	-.10 ns	-.06 ns	.23 ns	-.11 ns
BSRI-M1			.78 ****	.17 ns	.23 ns	.19 ns	.07 ns
BSRI-M2				.12 ns	.15 ns	.34 ns	.29 ns
GPA					.08 ns	.36 *	.45 **
GRADE						.31 ns	.20 ns
SE1							.40 *

* p < .05   *** p < .001
** p < .01   **** p < .001

Note. BSRI-F is excluded from table due to lack of any significant correlations.

Table 14

Matrix of Pearson Product-Moment Correlations Among Dependent and Independent Variables for Experimental and Non-experimental Subjects

	CRS1	PRB1	TSK1	MAS1	BSRIM	GPA	GRD	SE1
MSES1	.82 **** 162	.83 **** 162	.64 **** 162	.49 **** 162	.19 ** 157	.30 ** 102	.29 ** 111	.65 **** 162
CRS1		.62 **** 164	.44 **** 167	.47 **** 168	.21 ** 162	.47 **** 105	.42 **** 117	.65 **** 167
PRB1			.50 **** 166	.44 **** 166	.09 ns 161	.17 ns 106	.21 * 116	.59 **** 167
TSK1				.45 **** 169	.24 ns 163	.07 ns 106	.11 ns 119	.45 **** 169
MAS1					.05 ns 164	.09 ns 108	.29 *** 120	.65 **** 170
BSRIM						-.03 ns 103	-.16 ns 115	.15 ns 163
GPA							.51 **** 88	.34 *** 108
GRADE								.36 **** 120

* $p < .05$ *** $p < .001$
** $p < .01$ **** $p < .001$

Note. BSRI-F is excluded from table due to lack of any significant correlations.

Table 15

Stepwise Multiple Regression for Dependent Variable Final Statistics Grade

Dependent Variable: Final Statistics Grade (n=72)

Step	Variable Entered	Number In	Partial R2	Model R2	F	p
1	GPA	1	.1756	.1756	14.90	.0002
2	MAS	2	.1050	.2806	10.07	.0022

CHAPTER FIVE
DISCUSSION

All of the inferences drawn from this study must be made with caution since the numbers of subjects are so small. This study was conducted under the auspices of the Department of Psychology as a pilot for a program to serve undergraduate psychology majors enrolled in mandatory statistics classes. While its primary purpose was to test the ability of self-efficacy theory to explain changes in mathematical performance, the study was also constrained by the method by which students had to be recruited. Students could not be paid nor given extra credit for attending the groups, they had to attend voluntarily.

Even though students who had signed up to participate in the program were fully informed about the nature of the tutoring or confidence groups, many did not attend even the first session. This was unfortunate, though not unexpected given the tendency of people to avoid situations where they know they will be facing an anxiety-producing stimulus. Students who remained in the groups did not differ across groups. Students who did not persist in the tutoring groups had

lower scores on the self-estimate of math ability and math anxiety, however the tutoring group used in the analyses differed neither from the confidence group nor the control group at pre-testing.

Measures of Self-Efficacy:Self-Estimate of Math Ability and Math Self-Efficacy Scale

The self-estimate of math ability measure asked students to rate their ability in mathematics from "terrible" to "excellent." Only the students in the math confidence groups raised their ratings of their ability to a significant extent over the 6 week period. On the pretest, the confidence group participants rated their ability, on the average, between "poor" and "average," while the other groups had a mean rating of just over "average." By the end of the sixth session, the confidence groups rated themselves just under "good" while the tutoring and control groups' ratings remained virtually unchanged.

The self-estimate of math ability can be seen as another measure of self-efficacy, although a more general measure than the Math Self-Efficacy Scale. The moderate correlation between the post-tests of the Math Self-Efficacy Scale and the self-estimate of math ability suggests that the two measures are tapping the same construct to at least a moderate degree. The

self-estimate is significantly and positively correlated with the coursework subscale of the Math Self-Efficacy Scale which would suggest that when students are asked to rate their math ability they are focusing on their ability in math courses.

Because the groups were conducted with students currently enrolled in statistics courses, most of their concerns revolved around their performance in those particular classes. Perhaps the Math Self-Efficacy Scale, which asks many questions about specific problems and non-academic math tasks, was not a suitable measure for assessing changes produced in the confidence groups. Although the goal was to change general math self-efficacy, the 6 sessions did concentrate on changing self-efficacy as pertained to the statistics class. Perhaps the self-estimate measure was actually more sensitive to immediate changes since it appears to be assessing students' feelings about their ability in statistics classes.

Math Anxiety

Both the tutoring and confidence groups became less anxious over time, as measured by the Math Anxiety Scale. The confidence groups received direct training on how to manage physiological anxiety and related

cognitions, yet the tutoring groups received no such training. To conclude that the enrollment in the statistics class alone would reduce math anxiety would not account for the control group's complete lack of change. Perhaps the fact that the students volunteered for some sort of program to reduce anxiety and to build confidence produced an expectancy effect. When the means are examined, it can be seen that math anxiety scores decreased almost two times as much for the confidence group, however the time by group interaction was just above the .05 cutoff for significance. Once again, the small numbers of subjects may have reduced the power of the analysis.

Implications Grid

Self-efficacy was hypothesized to be influenced by students' stereotypes of mathematicians. The confidence groups spent a great deal of time trying to dispute negative stereotypes about mathematicians. The rationale was that if students could separate the ability to perform mathematics from more general personality traits which they perceived as negative, they would feel more free to enjoy and to succeed in math. In order to compare the influence of these stereotypes on other aspects of students'

self-concepts, an implications grid was used. The grid methodology is designed to show the relationships among various aspects of the person's self-concept. Students in the confidence groups decreased the number of implications on their grids to a degree that barely missed achieving statistical significance.

Supporting the inferences that it was the disputation of negative stereotypes that caused changes in the number of implications that math held for students' self-concepts, are the results of the analysis of confidence groups' homework assignments for the first and fifth sessions. In their second response to the question, "describe a typical mathematician," students in the confidence groups altered their negative stereotypes in the expected direction for many of the personality categories. Students used more terms that described mathematicians as actively involved in social interactions and fewer descriptors pertaining to forcefulness, organization, and external/factual descriptions such as gender, age, and physical characteristics. Very importantly, students in the confidence group made no comparisons between mathematicians and themselves in the first homework assignment, yet on the average, 6.47% of the adjectives

used on the last assignment involved self-references. This is encouraging since the aim of the groups was to show students they they too can be mathematicians.

The following is one example of a student's "before" and "after" descriptions of a typical mathematician:

> BEFORE:To me, a 'typical' mathematician is extremely intelligent, almost a genius. He's a tall, skinny male who doesn't pay enough attention to his appearance. He may wear old clothes and have an ancient hair style. His personality is dull-VERY DULL. I don't know about his social skills-this may be an area of divergence among the "mathematicians."

> AFTER:A person who enjoys math enough to want to make a career of it. A person who has a family, friends, and a life other than math. A person who has a life other than numbers. I wouldn't mind being a friend of a mathematician. (I just realized as I wrote this that my big sister in my sorority [and a very close friend] is a MATH MAJOR! and she's very human to me.)

Final Course Grade

There were no differences among the groups in regard to final course grade. Grade was to be used as a behavioral outcome measure, a dependent variable usually absent from intervention studies in this area. All of the attitudinal changes in the world are useless

if the behavior in question cannot be affected positively. In this case, neither the tutoring nor the confidence groups performed significantly better in their statistics courses than students in a no-treatment control. Perhaps it is unrealistic to expect a six week intervention to effect any change in statistics/math performance. Students have already had years of math avoidance and poor performance. A better measure may have been the trend in math homework and quiz grades.

Post-hoc Correlational Analyses

The failure of the confidence groups to change according to prediction does not mean Bandura's self-efficacy theory is not useful in the explanation and prevention of math avoidance. Some correlational analyses done on the experimental and non-experimental groups support the findings of earlier research in this area.

For both groups, Math Self-Efficacy Scale scores and Math Anxiety Scale scores were moderately correlated; as math self-efficacy increases, math anxiety decreases. These findings support Bandura's contention that math anxiety is a "coeffect" of low math self-efficacy. When students feel unable to

complete math tasks their level of anxious thoughts and feelings begin to rise. Self-estimate of math ability was also related to math anxiety in the same direction for both groups, providing further evidence that self-estimate and Math Self-Efficacy are measuring similar constructs.

There is some evidence that self-efficacy is related to actual behavior, though no causal inferences can be made from these correlations. For the large, non-experimental group, Math Self-Efficacy scores and final course grade had a low to moderate relationship. For the non-experimental group, as math self-efficacy increased, final statistics grade also increased. The coursework subscale of the Math Self-Efficacy Scale had the highest correlation with final grade followed by the problem subscale. The task subscale did not have any significant relationship to final course grade. This makes sense since the coursework and problem subscales are more likely to tap skills used in the course than the mathematical tasks subscale. For the experimental group, however, only the task subscale correlated significantly with the final grade.

For the non-experimental group, self-estimate is also related to final grade to a small but significant

extent. Students in statistics classes appear to be only moderately able to predict their actual course performance. Scores of students in the experimental group showed no significant relationship between their self-estimates of math ability and their final course grade.

The multiple regression analyses conducted on the non-experimental group shows that after grade point average, math anxiety is the best predictor of course grade. This is not what might be expected according to Bandura, who sees math anxiety as merely a byproduct of low math self-efficacy. Although the analyses was conducted on a subgroup of the non-experimental group who had scores for all of the variables, it makes one cautious about dismissing "math anxiety" as a predictive variable.

Grade point average and math self-efficacy scores as measured by both the Math Self-Efficacy Scale and the self-estimate of math ability, were significantly related for the non-experimental group, so that one's perceived ability to succeed in math appears to have an impact on one's overall academic performance. Grade point average and self-estimate were related for the experimental group as well.

Finally, there were several findings of interest in terms of Betz and Hackett's (1983) study. In their research, they found that the masculinity scale of the Bem Sex Role Inventory was related to the scores of the Math Self-Efficacy Scale. The current study supports this relationship to a small, yet significant degree, however analyses were conducted on the combined group of men and women. For non-experimental subjects, as masculinity rises so does math self-efficacy, especially for the coursework subscale. Evidently, masculine self-concept facilitates one's feelings of efficacy in regard to coursework though apparently not in regard to mathematical tasks and problems. Curiously, there is a rather strong negative relationship between the task subscale and the masculinity score for experimental subjects that disappears on the posttest. This finding would mean that as masculinity increased, scores on the task subscale decreased. There is not logical explanation that easily accounts for this finding in the absence of correlations with other subscales.

Femininity scores had no relationship to any of the other variables in the correlation matrix as was the case in the Betz and Hackett (1983) study. It

appears that only qualities traditionally associated with masculinity facilitate feelings and beliefs about performing in math. This lends some support to the thesis that messages about the "appropriateness" of math may influence confidence in a positive direction. Girls who possess these "masculine" characteristics would also be more likely to feel efficacious in regards to mathematics. These findings are also in line with Hackett (1985) whose path analysis demonstrated the importance of masculinity (as measured by the Bem Sex Role Inventory) on self-efficacy.

Limitations of Confidence and Tutoring Groups

Rather than blaming the failure to support all hypotheses solely on the measures used and on the small numbers of subjects, it must be acknowledged that there were some difficulties with the confidence and tutoring groups themselves. Students in the former groups were less than fully committed to completing homework assignments and to self-monitoring exercises. Since these activities were designed to focus students' awareness on the power of cognitions to affect behavior, a lack of attention to these tasks surely diluted the confidence groups' effectiveness. One might expect that if there were a greater reward for

completing these assignments students would have been more inclined to comply. However, as previously mentioned, this type of reward system was not feasible nor fair given the restraints of departmental policies.

An equally serious problem with the tutoring groups was the lack of consistent attendance. Students in the tutor groups attended significantly fewer sessions than did those in the confidence groups. Unfortunately, with so few subjects it is impossible to account for the role attendance played in pre- to post-test changes. The lack of attendance is not a new problem encountered by academic departments which offer remedial services. Discussion groups offered by the Department of Statistics at this university were often sparsely attended except before exams. The fact that more of the members of the confidence groups persisted for 6 weeks may say something about the role of peer support on group adhesion.

One of the ideas behind the confidence groups was that if one could convince students that their cognitions were interfering with their ability to perform well in math while simultaneously making them aware of how they could improve their math study skills, they would be able to use already-existing

capabilities to learn new material in their statistics classes. Perhaps this is idealistic. Siegel et al. (1985) recommend combining counseling techniques with actual math instruction that goes beyond tutoring. It is probably naive to expect that a short term intervention, no matter how successful in carrying out its goal of increasing self-efficacy, will compensate for years of unlearned and avoided mathematical principles. Bandura (1982) has demonstrated that the "performance attainments" component of self-efficacy is the most important in changing future behavior. It was intended that the performance accomplishments would come in the statistics classes. It may have been better to link the cognitive training students received in the groups with more immediate "hands on" statistics lessons during the group sessions.

Further studies would be wise to include an intensive math instruction component along with techniques to raise self-efficacy. Although self-efficacy, the belief in one's ability to perform a task, still appears necessary before one can complete or be motivated to complete a task, merely wishing to do well will not make it so! Completing an ANOVA in

statistics class is substantially different than petting a snake!

Conclusion

In spite of the very small numbers of students who participated in the confidence and tutoring groups throughout the six week period, the groups still managed to effect some changes on students' perceptions of their ability to do mathematics, in the level of their anxiety about math, and in the way they viewed doing mathematics as affecting the other parts of their personality. There are many difficulties in administering a remedial program such as was attempted here. People who have managed to deal with their anxiety and lack of confidence about a certain issue or task for many years by avoiding all contact are not easily persuaded to wholeheartedly abandon their avoidance behavior in favor of confronting and overcoming their fear. They may sabotage their success by not attending sessions or by neglecting to complete integral assignments. These are problems familiar to counselors in all areas.

The modest successes that have resulted from this program seem to indicate that such an intervention is worthwhile. Mathematics will only become more important

in the decades to come. Although it is important to focus on programs that insure that all children have the opportunity to learn and to enjoy mathematics in an anxiety-free atmosphere, we must not abandon those who were not fortunate to have had such experiences during their early school years. We do not give up on adults who have not learned to read or write, neither should we forget those who lack mathematical literacy.

APPENDIX 1

LETTER OF INTRODUCTION TO NEW PSYCHOLOGY MAJORS

Dear Psychology Major:

Welcome to the Department of Psychology! the College of Liberal Arts and Sciences has approved your declaration of psychology as a major. We hope and trust that the training you seek is an enjoyable experience for you. Please know that the department is organized in a fashion to be responsive to your needs and requests. There are a number of resources that you should avail yourself of throughout your career as a psychology major. First and perhaps foremost in importance is our departmental advising center. This is located in room 163 of the Psychology Building. We suggest that you drop by the office as soon as possible in order to have a discussion with one of the psychology advisors regarding your curriculum plans. We like to see students periodically, at least once a year, and help with any questions they may have regarding the appropriate sequencing of courses, scheduling of certain hurdles in program, and advice regarding the preparation of application materials for graduate or professional schools, etc. There is also information available regarding careers in psychology, other training programs, etc.

It is our sincere hope that we make the undergraduate program a meaningful and enjoyable one. Our suggestions regarding the appropriate sequencing of classes are based upon the premise that early courses provide the framework and foundation for later courses. A student will do better in later courses if one has completed the foundation level courses. Also, we hope that students will finish required courses in time to expose themselves to "senior seminar" classes offered by most areas in the department some time before they graduate. We feel that these revolving topic seminars, in addition to the cap-stone experience of laboratory classes (research method classes) and/or a senior thesis, provide very good science-based training and will prepare you for further professional or graduate training or an employment position requiring a four-year (B.S.) degree.

As a function of our commitment to be as supportive as is possible, we are embarking upon a pilot program. Attached you will find a rating scale that we ask you to complete and, either mail back to us, or drop by our advisement office. Specifically, we

are interested in those individuals who are somewhat apprehensive regarding math, statistics, and the science aspects of our training program. The enclosed screening device allows us to identify individuals who either may have some problems in this area or, in fact, feel they are extremely gifted in these areas. Although completion of this screening device is voluntary, we strongly request and advise that you send the information back to us and allow us to develop supportive programs based on your feeling and orientations on these matters. It will only take about ten minutes of your time and the real purpose of the effort is to be as helpful and supportive to the undergraduate majors as we have the skills to be. Again, I welcome you to the program and look forward to interacting with you in the next several years.

Sincerely yours,

Lawrence J. Severy
Professor, and Director of
Undergraduate Studies

APPENDIX 2

BETZ AND HACKETT MATHEMATICS SELF-EFFICACY SCALE

Please indicate your level of confidence that you could successfully perform the problems or tasks listed below. For example, if you have no confidence in your ability to perform a task you would write "0," but if you have complete confidence that you could perform a task you would write "9." Do not attempt to solve any problems, just indicate your confidence that you could solve the problem if asked.

(no confidence)									(complete confidence)
0	1	2	3	4	5	6	7	8	9

______ Work with a slide rule

______ Determine how much interest you will end up paying on a $675 loan over 2 years at 14 3/4% interest

______ Figure out how much lumber you need to buy in order to build a set of bookshelves

______ Compute your income taxes for the year

______ Figure out how much material to buy in order to by curtains

______ Understand a graph accompanying an article on business profits

______ Understand how much interest you will earn on your savings account in 6 months, and how that interest is computed.

______ Add two large numbers (e.g. 5739 + 62543) in your head

______ Estimate your grocery bill in your head as you pick up items

______ Determine the amount of sales tax on a clothing purchase

______ Figure out the tip on your part of a dinner bill split 8 ways

______ Figure out how long it will take to travel from City A to City B driving at 55 mph

______ Compute your car's gas mileage

______ Set up a monthly budget for yourself

______ Balance your checkbook without a mistake

______ Figure out which of two summer jobs is the better offer, one with a higher salary but no benefits, the other with a lower salary plus room, board, and travel expenses

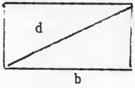
______ Figure out how much you would save if there is a 15% markdown on an item you wish to buy

______ Calculate recipe quantities for a dinner for 41 when the original recipe is for 12 people.

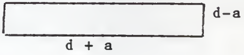
______ In Starville, an operation o on any numbers a and b is defined by a o b = (a + b). Then 2o3 equals____?

______ Sally needs three pieces of poster board for a class project. If the boards ae represented by rectangles A, B, C, arrange their areas in increasing order. (assume b>a)

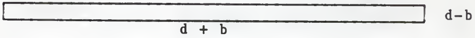
A.



B.



C.



______ The average of three numbers is 30. The fourth number is at least 10. What is the smallest average of the four numbers?

______ To construct a table, Michele needs 4 pieces of wood 2.5 feet long for the legs. She wants to determine how much wood she will need for five tables. She reasons: 5 X (4 X 2.5). Which number principle is she using?

______ The opposite angles of a parallelogram are ______?

______ Five points are on a line. T is next to G. K is next to H. C is next to T. H is next to G. Determine the relative positions along the line.

______ In a certain triangle, the shortest side is 6 in., the longest side is twice as long as the shortest side, and the third side is 3.4 in. shorter than the longest side. What is the sum of the three sides in inches?

______ The hands of a clock form an obtuse angle at ____ o'clock?

______ Bridget buys a packet containing 9-cent and 13-cent stamps for $2.65. If there aare 25 stamps in the packet, how many are thirteen cent stamps?

______ A living room set consisting of one sofa and one chair is priced at $200. If the price of the sofa is 50% more than the price of the chair, find the price of the sofa.

______ Write an equation which expresses the condition that "the product of two numbers R and S is one less than twice their sum."

______ Set up the problem to be done to find the number asked for in the expression "six less than twice 4 and 5/6?

______ On a certain map, 7/8 in. represents 200 miles. How far apart are two towns whose distance apart on the map is 3 1/2 inches?

______ The formula for converting temperature from degrees Centigrade to degrees Fahrenheit is F=9/5C + 32. A temperature of 20 Centigrade is how many degrees Fahrenheit?

______ 3 3/4 - 1/2 = _____?

______ If 3x - 2 = 16 - 6x, what does x equal?

______ Fred's bill for some household supplies was $13.64. If he paid for the items with a $20, how much change should he receive?

Please indicate your level of confidence that you could complete the following courses with a grade of "B" or better.

(No confidence) (Complete confidence)

0 1 2 3 4 5 6 7 8 9

______ Advanced calculus
______ Calculus
______ Biochemistry
______ Statistics
______ Computer Science
______ Physiology
______ Trigonometry
______ Economics

_____ Zoology
_____ Accounting
_____ Philosophy
_____ Bus. Administration
_____ Geometry
_____ Algebra II
_____ Algebra I
_____ Basic College Math

APPENDIX 3

FENNEMA-SHERMAN MATHEMATICS ANXIETY SCALE

Please use the following scale to respond to the questions in Part II.

1=Strongly Disagree 2=Disagree 3=Undecided 4=Agree 5=Strongly Agree

1. _____ It wouldn't bother me at all to take more math courses.
2. ____ I have usually been at ease during math tests.
3. ____ I have usually been at ease in math courses.
4. ____ I usually don't worry about my ability to solve math problems.
5. ____ I almost never get uptight while taking math tests.
6. ____ I get really uptight during math tests.
7. ____ I get a sinking feeling when I think of trying hard math problems.
8. ____ My mind goes blank and I am unable to think clearly when doing mathematics.
9. ____ Mathematics makes me feel uncomfortable and nervous.
10. ____ Mathematics makes me feel uneasy and confused.

APPENDIX 4

BEM SEX ROLE INVENTORY

Please rate yourself on each item on a scale from 1 (never or almost never true) to 7 (always or almost always true).

(Never or almost never true)						(Always or almost always true)
1	2	3	4	5	6	7

1. ____ self-reliant
2. ____ yielding
3. ____ helpful
4. ____ defends own beliefs
5. ____ cheerful
6. ____ moody
7. ____ independent
8. ____ shy
9. ____ conscientious
10. ____ athletic
11. ____ affectionate
12. ____ theatrical
13. ____ assertive
14. ____ flatterable
15. ____ happy
16. ____ strong personality
17. ____ loyal
18. ____ unpredictable
19. ____ forceful
20. ____ feminine
21. ____ reliable
22. ____ analytical
23. ____ sympathetic
24. ____ jealous
25. ____ has leadership abilities
26. ____ sensitive to needs of others
27. ____ truthful
28. ____ willing to take risks
29. ____ understanding
30. ____ secretive
31. ____ makes decisions easily
32. ____ compassionate
33. ____ sincere
34. ____ self-sufficient
35. ____ eager to soothe hurt feelings
36. ____ conceited
37. ____ dominant
38. ____ soft-spoken
39. ____ likable
40. ____ masculine
41. ____ warm
42. ____ solemn
43. ____ willing to take a stand
44. ____ tender
45. ____ friendly
46. ____ aggressive
47. ____ gullible
48. ____ inefficient
49. ____ acts as a leader
50. ____ childlike
51. ____ adaptable
52. ____ individualistic
53. ____ does not use harsh language
54. ____ unsystematic
55. ____ competitive
56. ____ loves children
57. ____ tactful
58. ____ ambitious
59. ____ gentle
60. ____ conventional

APPENDIX 5

BACKGROUND INFORMATION QUESTIONNAIRE

NAME______________________________ PHONE #______________

SOCIAL SECURITY # ____________________________

CLASS (junior, senior, etc.) ________________

PLEASE LIST MATH/STATISTICS COURSES TAKEN IN HIGH SCHOOL

1.______________ 2.______________

3.______________ 4.______________

HAVE YOU EVER BEEN ENROLLED IN STA 3023 OR STA 3024?

Yes ____ No ___

ARE YOU PRESENTLY ENROLLED IN STA 3023 OR STA 3024?

Yes ____ No ____ If so, which course? ______

HOW DO YOU CONSIDER YOUR MATH ABILITY TO BE?

___ TERRIBLE ___ GOOD

___ VERY POOR ___ VERY GOOD

___ POOR ___ EXCELLENT

___ AVERAGE

APPENDIX 6

IMPLICATIONS GRID

Choose seven traits you like most about yourself and list them in the left column on the next page. Next to each of these traits, list what you consider to be the opposite of that characteristic or trait. For instance, if you listed "kind" as one of your positive traits you might consider "unkind" to be the opposite of "kind." You would write "unkind" in the right column next to "kind." When you reach lines 8, 9, and 10, circle the trait that best describes you right now regardless of whether or not it is in the left column.

Now consider the positive trait you wrote in blank number 1. Now, if you were to be changed back and forth from one column to the other-that is, if you woke up one morning and realized that you were best described by the trait in the right column while the day before you had been best described by the trait in the left column,- if you realized that you were changed in this one respect, what other traits of the remaining nine would be likely to be changed?

Going across the first row of the grid, place a check mark in each numbered box that represents a trait that would also be changed as a result of a change on trait number 1. If a change in trait 1 would have no influence on a particular trait you would leave the box blank. Continue this process for traits 2-10.

Positive Traits	Opposites
1. ______________	______________
2. ______________	______________
3. ______________	______________
4. ______________	______________
5. ______________	______________
6. ______________	______________
7. ______________	______________
8. mathematician	non-mathematician
9. math confident	math anxious
10. feminine	masculine

	1	2	3	4	5	6	7	8	9	10
1.	X									
2.		X								
3.			X							
4.				X						
5.					X					
6.						X				
7.							X			
8.								X		
9.									X	
10.										X

APPENDIX 7

MATH CONFIDENCE GROUP OUTLINES
(Probert, 1983, revised by Forbes)

SESSION ONE

I. Confidentiality Policy

II. Contract
III. Introductions

IV. Self-Monitoring
  A. Graphs
  B. Journals

V. "Picture a Mathematician"

VI. Math Myths
  A. Which ones do you believe?
  B. What do you give up by not doing math/statistics?
  C. What do you give up by doing math/statistics?

VII. Why do we avoid math and statistics?

VIII. Irrational Beliefs and How to Change Them

IX. Relaxation

Homework I

1.a. In a paragraph, write a description of yourself. Be sure to include the following: intelligence, appearance, personality, social skills.

b. Using the same characteristics as above, write a brief description of someone you think is a "typical" mathematician.

c. How similar or different are these two descriptions? How much would you have to change to become like the mathematician?

2.Think of yourself as possessing a fixed quantity of energy or willpower. How much of this willpower do you use when it comes to learning math? Draw a diagram to illustrate this.
If you could give names to the parts of you who do and do not want to learn math, what would they be? What do they look like?

3. What is the most frightening thing about doing math?

APPENDIX 7

Session Two

I. Review and Discussion

II. Time Management

   A. Procrastination
   B. Lakein's ABC's of scheduling

III.Study Skills
   A. SQ3R Study Method
   B. Flashcards

IV. Assignments

V. Relaxation-Visualizing Success

Homework II

1. Identify three ways in which you procratinate. List several methods you can use to reduce procrastination.

2. What are some of the benefits of putting off statistics?

3. What are some of the drawbacks of procrastinating in statistics?

4. On the back of this page, outline a chapter in your statistics book using the SQ3R method.

5. Write three positive statments about yourself and your abilities that you can use before a test or before studying.

APPENDIX 7

Session Three

I.Review and Discussion

II.Progressive Deep Muscle Relaxation

III. Assessing Your Stress Level
- A. Stress Test
- B. Mood Symptom Response Test
- C. Anxious Functioning

IV. Handling Your Stress

V. Test Taking Strategies

VI. Relaxation

Homework III

1. Discuss "anxious functioning" in terms of your own test taking behavior. What happens to your body and to your thoughts when you feel anxious?

2. Describe a situation where your anxiety negatively affected what you were trying to accomplish (it does not have to involve math). If you could relive this situation, what would you do differently? How do you think the outcome would change?

3. For the next ten minutes, do something you find relaxing. Describe what you did and any changes you noted in the way you felt, both physically and mentally.

4. Write down your strategy for preparing for the next test. Include study time, relaxation, self-talk. Be sure to plan for "moments of panic" that migh creep up during the test. Take a few minutes and imagine yourself going through each of the steps in your plan.

APPENDIX 7

Session Four

I. Review and Discussion

II. Problem Solving

A. Polya's How to Solve it Formula for problem solving

1.Used two ways:
-To solve math problems
-To solve math confidence "problems"

2.Four steps:
-Understand the problem
-Devise a plan
-Carry out the plan
-Examine the solution, reassess

B. Solving a word problem

1. What is the question?
2. Organize the information
3. What are my thoughts and feelings as I work on the problem?

III.Setting Goals

IV. Homework

V. Relaxation and Visualization

Homework IV

1. Discuss some things you have learned about yourself by participating in this group.

2. Describe a "typical mathematician." What does this person look and act like? Would you like to have this person as a friend?

3. Construct a diploma or certificate of achievement for the person whose name appears below yours on the group list.

APPENDIX 7

Session Five

I. Review and Discussion

II. Posttesting

III. Presentation of "Diplomas"

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BIOGRAPHICAL SKETCH

Karen J. Forbes was born on September 17, 1961 in Newark, New Jersey. She attended the public schools in Bloomfield, New Jersey where she was active in music activities on the local, state, and national level. She attended Oberlin College where she majored in psychology and continued to study voice and to perform with the Oberlin College Choir. She was graduated with Honors in 1983 and was granted membership in Sigma Xi.

As a graduate student at the University of Florida, Ms. Forbes has led several math confidence groups for graduate and undergraduate students and for elementary education majors. She conducted vocational, couples, and individual counseling at the Psychological and Vocational Counseling Center and Student Mental Health Services and was a graduate instructor for three semesters. In 1985, Ms. Forbes received her M.S. in psychology. She has been awarded a graduate assistantship from the Division of Sponsored Research and has received the President's Recognition Award for her achievements.

During the academic year 1986-87, Ms. Forbes was the Assistant Director of College Planning, a private

educational consulting firm in Rockville, Maryland. She will complete her doctoral internship at the Center for Counseling and Student Development at the University of Delaware in August 1988. Ms. Forbes lives with her husband, Larry Gage, in Newark, Delaware.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Greg J. Neimeyer

Greg J. Neimeyer, Chairperson
Associate Professor of
Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Helen L. Mamarchev

Helen L. Mamarchev
Associate Professor of
Counselor Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Barbara S. Probert

Barbara S. Probert
Counseling Psychologist

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Paul G. Schauble
Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Lawrence J. Severy
Professor of Psychology

This dissertation was submitted to the Graduate Faculty of the Department of Psychology in the College of Liberal Arts and Sciences and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1988

Dean, Graduate School